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JOURNAL
OF THE
AMERICAN SOCIETY OF NAVAL ENGINEERS

VOL. 49. MAY 1937. No. 2

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THE DEAERATION OF BOILER FEED WATER.

BY LIEUTENANT COMMANDER R. W. BRUNER, U. S. NAVY, MEMBER.*

As methods for treating boiler feed water have improved, and marine engineers have increasingly turned their attention to the need for greater cleanliness of the waterside, it is becoming apparent that there is a distinct possibility that modern cleanliness may not be an unmitigated blessing. Perhaps some reasonable amount of scale served a useful purpose in guarding clean metal from oxygen attack, and perhaps a permanent oxide film served other purposes than merely to increase the heat transfer coefficient. There is much discussion along such lines these days, and Commander Bruner's discussion of oxygen elimination and reduction is therefore timely, and interesting to all ship engineers. Marine boilers become more efficient with each new design, and weight factors are dropping daily. But this means that there is less metal in them to start with, and it follows that they are more vulnerable than the boilers of twenty years ago to an insidious disintegration into Fe_2O_3 *and* Fe_3O_4.

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INTRODUCTORY.

Internal corrosion in Naval or Marine boilers is attributable to corrosive agents in the boiler water, such as dissolved oxygen, organic or fatty acids, and to dissolved salts including magnesium chloride. Corrosion of ferrous boiler surfaces may manifest itself by localized pitting of concentrated character, by a generally uniform surface attack, or infrequently by grooving. To prevent corrosion it becomes necessary to eliminate oxygen from boiler feed water and further continue to exclude it from the condensate and feed system, to provide distilled feed of the best attainable purity, to neutralize any remaining or increasing concentration of corrosive elements by a suitable chemical treatment of boiler water, to prevent the entry of contaminating lubricating oils in the feed water, and perhaps to protect boiler surfaces by a thin coating of a neutral substance. Many or all of such methods may be employed, but their present application has not as yet reached that degree of perfection wherein boiler corrosion has been entirely eliminated. Yet upon their successful application will depend the life of the boiler, its efficiency, reliability and safety.

A familiar example illustrating in a general way that the extent of corrosion is approximately proportional to the amount of oxygen in solution in the water is found in domestic heating equipment in the home. It has been stated that hot water heating systems with closed water circulation show practically no corrosion after thirty years or more of use while hot water supply systems operating at about the same temperature usually require partial or complete renewal at least every eight years. The only essential difference between the two systems lies in the fact that the heating system is vented practically free of air while the water supply system is continuously receiving water heavily saturated with air.

In many authoritative engineering text books published about twenty years ago, the dangers of oxygen corrosion and a description of the deaeration process was usually given scant attention or omitted entirely. In England the Weir, Contraflo, and other deaerating systems were first developed and excellent results were obtained. In the United States the advantages of deaeration were soon apparent and manufacturers developed a wide variety of excellent feed systems for large power plants and central station application.

During the last several years its application to Naval and Marine uses has been receiving the study and interest of engineers, commendable progress has been made, and development is rapidly continuing.

THEORIES OF CORROSION.

In discussing the subject of corrosion it is desirable to briefly review the proposed or accepted theories which have been evolved to explain this phenomenon. Originally it was believed that corrosion occurred by pure oxidation as in the case of heating an iron bar in air. The discovery of the influence of oxygen in conjunction with moist air or liquid water led to the acid theory of corrosion. Carbonic acid in addition to oxygen and water was assumed to be present in the corrosion environment. The acid uniting chemically with the iron formed a ferrous salt which was oxidized to ferric hydrate and the acid radical was liberated for further corrosive activity. This theory indicates a continued and repeated corrosion attack with the presence of minute initial quantities of acid.

The electrolytic theory was next established and is now the most generally accepted explanation of corrosion. In certain experiments polished samples of iron suspended in test tubes, sealed while distilled water in them was at the boiling point to exclude air and tightly corked, indicated no rusting whatever over a long period of time. When air was finally admitted a ferric hydrate precipitate formed and corrosion progressed rapidly. Based on this theory with water and iron in contact, the iron goes into solution as the hydrogen ions plate out on the iron surface. The hydrogen ions act much as metal ions in their plating action. For example, if iron is placed in a solution of copper sulphate, the iron goes into solution and the copper sulphate plates out on the iron. If the action were violent the hydrogen might appear as an escaping gas. Usually, however, it plates out as an insulating gaseous film on the surface and in this case further electrolytic action would be prevented by polarization. Actually the chemical action of the oxygen supplied by the feed water and the mechanical sweeping action of the circulating boiler water combines to remove the insulating film of hydrogen and thus prevent polarization and corrosion proceeds. In a neutral water the amount of ionized hydrogen H equals the

amount of ionized hydroxyl OH or $H_2O = H + OH$. In a boiler water of acid reaction the number of hydrogen ions increase in relation to the hydroxyl ions and in water of an alkaline reaction the relationship is reversed. Thus corrosion is more rapid in a neutral or acid reaction than in an alkaline reaction since the reduction of ionized hydrogen also reduces electrolytic cell action. If, however, alkalinity is carried beyond permissive limits a form of localized corrosion also occurs. These reactions of the electrolytic theory do not take place in dry air or in water free from oxygen.

The hydrogen peroxide theory is based upon the formation of hydrogen peroxide as an intermediate step of acid corrosion and rust formation. It does not appear to be well substantiated.

The biological theory presumes the corrosion of iron as due chiefly to micro-organisms. No possibility of its application to boiler conditions exists since the boiler would be a most efficient high temperature sterilizer in destroying such organic forms.

The rate of corrosion of both ferrous and also non-ferrous metals has been found to be determined by the concentration of dissolved oxygen in solution, by the temperature of the water, by the nature of the metal surface and by the degree of active acidity or alkalinity of the water. The last factor mentioned and discussed above under the electrolytic theory is frequently described as the hydrogen ion concentration or pH value. A neutral solution has a pH value of 7.0 while an acid solution has a lesser value and an alkaline solution a greater value.

SOLUBILITY OF OXYGEN.

The purpose of this article is not, however, to discuss the manifold causes of corrosion enumerated, but to consider only the contributory part of dissolved oxygen in its relation to boiler surface corrosion. Iron and steel materials used in boilers, piping, economizers, superheaters, turbine blading and other engineering apparatus will be corroded if in contact with water containing oxygen in solution. The amount of linear penetration of this corrosion has been found to be approximately a straight line relationship to water temperature. Hot water at 210 degrees F. has been found under given conditions to produce twice the depth of corrosion as compared to cold water at 85 degrees F. The weight of iron which

can be converted into rust has also been found to increase in proportion to the oxygen content of the water in contact. All water has a strong tendency to absorb air which increases with the higher pressures and decreases with increased temperatures. The oxygen of the air has a marked affinity for iron and produces oxide of iron in the presence of moisture. The roughened metallic surface thus produced provides an opportunity for a further rapidly increasing corrosion.

The solution of a gas in a liquid has been considered by some investigators to be a mixture of two liquids consisting of the dissolving liquid and the dissolved gas. Water may, however, have a certain amount of entrained air in addition to that held in solution. Figure 1 indicates graphically the extent to which a rise in temperature decreases the solubility at atmosphere pressure. Water at 80 degrees F. contains less than one-sixth as much dissolved oxygen as water at 40 degrees F. Figure 2 indicates solubility variations existing at vacuum conditions in the low temperature range shown

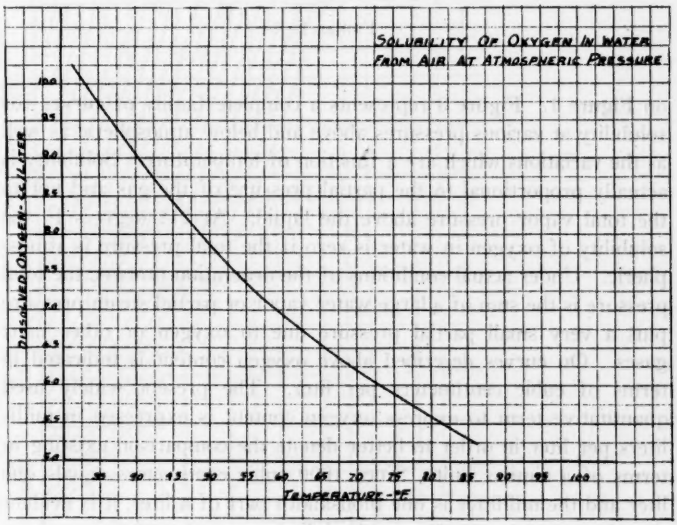

FIGURE 1.

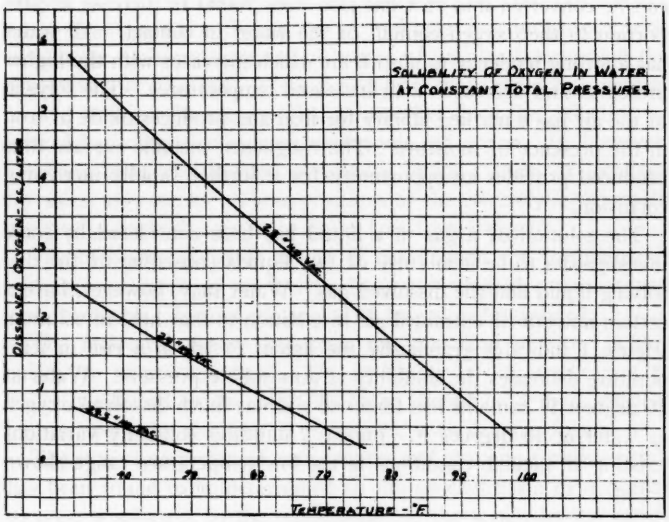

FIGURE 2.

on Figure 1. Figure 3 represents a complete family of curves for solubility at various pressures above and below atmospheric as well as the variations which are a function of temperature. Solubility is actually proportional to the partial pressure of the gas and not to the total vapor pressure above the liquid. At 212 degrees F. the solubility of oxygen in water is zero if the total pressure is atmospheric. Under actual conditions of the deaeration process, the total pressure is the sum of a large water vapor or partial steam pressure plus a very small partial pressure due to oxygen or other inert gases. On curves described above oxygen content is indicated in terms of cubic centimeters per liter. The present widely used quantitative term to express oxygen content is expressed in milliliters per liter in order to better denote the comparison existing in terms of a similar unit. Since 1000 cubic centimeters equals one liter and the milliliter is one thousandth part of a liter, it is evident that the two terms, cc/liter and ml/liter are synonymous.

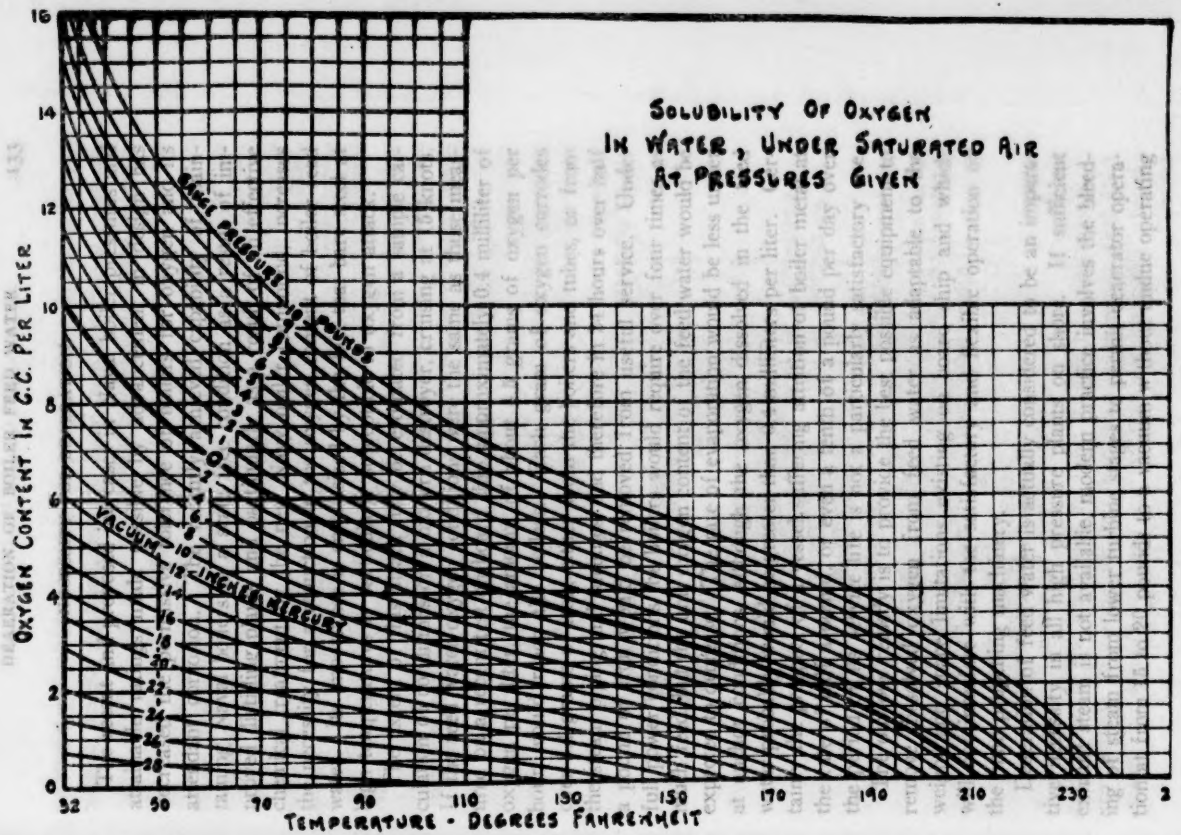
SOLUBILITY OF OXYGEN
IN WATER, UNDER SATURATED AIR
AT PRESSURES GIVEN
GAUGE PRESSURE
POUNDS
VACUUM
INCHES MERCURY
OXYGEN CONTENT IN C.C. PER LITER
TEMPERATURE - DEGREES FAHRENHEIT
0
2
4
6
8
10
12
14
16
32
50
70
90
110
130
150
170
190
210
230

FIGURE 3.

NECESSITY FOR DEAERATION.

The recent and proposed increases in Naval boiler pressures and attainable ratings made possible by advancement in design has decreased the permissive tolerance of boilers for oxygen and its attendant corrosion. The recently achieved capability of maintaining Naval boilers in a scale free condition as a result of improved distilling plants and particularly as a result of an effective chemical treatment by the new Navy boiler compound, increases the necessity for a reduction in the oxygen content of boiler feed water. Its importance is emphasized by the fact that bare steel at high temperatures is particularly susceptible to oxygen attack.

The extent of this attack may be estimated from a sample calculation of conditions on a modern destroyer, cruising at 15 knots. If the feed water oxygen conditions were the same as those measured on a recent test on board ship, approximately 0.4 milliliter of oxygen per liter, the amount of about 4.5 grams of oxygen per hour would reach the boilers. Each gram of oxygen corrodes over 2.4 grams of iron, either from the boilers and tubes, or from the steam piping and turbines, and therefore in 24 hours over half a pound of iron would be removed from useful service. Under full power conditions the boilers would require over four times as much feed, but the unit oxygen content of the feed water would be expected to decrease. The rate of evaporation would be less under at anchor conditions, although the oxygen dissolved in the feed water probably would be greater than 0.4 milliliters per liter. Certainly the prospect of a vessel suffering attrition of boiler metal at the rate of half a pound, or even a tenth of a pound per day over the period of its service life is not a particularly satisfactory one.

The obvious remedy is to provide the best possible equipment to remove dissolved oxygen from feed water as adaptable to the weight and space limitations existing on board ship and which will not interfere with the satisfactory and flexible operation of the main propelling machinery.

Deaeration of feed water is actually considered to be an imperative necessity in all high pressure plants on shore. If sufficient exhaust steam is not available, modern practice involves the bleeding of steam from lower turbine stages to permit deaerator operation at from 15 to 20 pounds to a vacuum without undue operating

attention. A closed feed heater frequently precedes the deaerator in order to utilize lower bleed pressures and to prevent a wide range of deaerator operating pressure.

DEAERATION EQUIPMENT.

In land power plants such deaerator equipment is usually in the form of a direct contact low pressure feed heater with agitation of the incoming feed, to release the contained oxygen. The basic principle of all deaerators of the open heater type relies upon the fact that water at the boiling point and in contact with steam cannot retain a gas in solution.

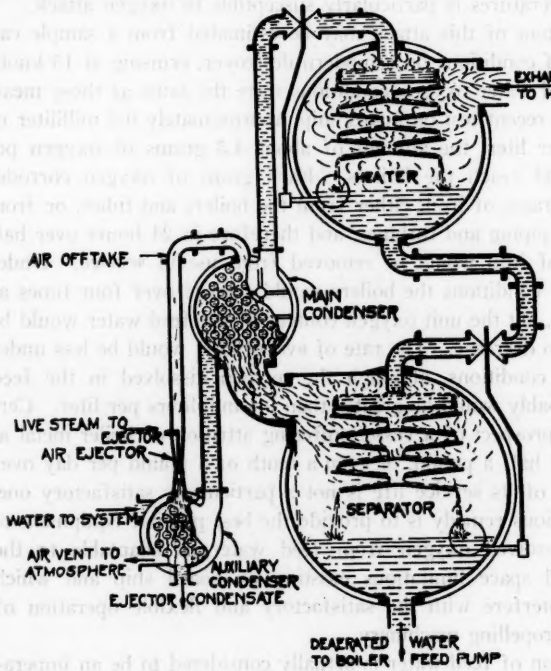

FIGURE 4—VACUUM TYPE DEAERATOR.

A description of several types of equipment will serve to illustrate both the principles utilized and the apparatus actually employed. Diagrammatic sketches are used to simplify the presentation.

A deaerator widely used in land practice is shown in outline in Figure 4. In this type, heated water is injected into a vacuum space where violent and explosive boiling occurs to effect liberation of dissolved gases. The incoming feed water passes through the air ejector after condenser and vent condenser and is next introduced into a heater chamber which is supplied with exhaust steam. Shallow cascading trays provide for direct contact heating of the feed water which then flows into a separator shell mounted below and also fitted with distribution trays. The single stage air ejector removes vapor and dissolved gases. The vapor is condensed in the vent condenser and returns to the separator shell while air and non-condensible gases are expelled to atmosphere after passing through the air ejector after condenser. Feed pump suction of the deaerated water is taken from the bottom of the separator shell.

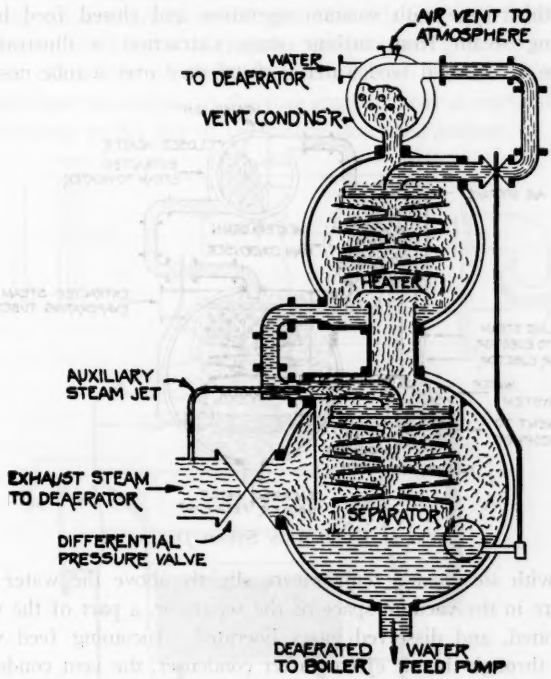

FIGURE 5—PRESSURE TYPE DEAERATOR.

Another type wherein vacuum application is not utilized is illustrated diagrammatically in Figure 5. Heated feed water is introduced into a separator shell and subjected to the sweeping action of steam at the same temperature as that of the water, and dissolved gases are liberated. The incoming feed water passes through a vent condenser to the trays in a heater chamber where the rising steam from the separator shell imparts a heating effect. The water next flows into the lower separator chamber and additional heat is added by an auxiliary steam jet. In the separator chamber the water, in its passage over a tray arrangement, is subjected to the sweeping of incoming exhaust steam, a deaerating effect is provided, the steam flows upward in the heater shell and the liberated gases flow through the vent condenser to atmosphere. Main feed pump suction is provided at the bottom of the separator shell.

A third type with vacuum operation and closed feed heaters utilizing steam from turbine stage extraction is illustrated in Figure 6. Heated feed water is distributed over a tube nest sup-

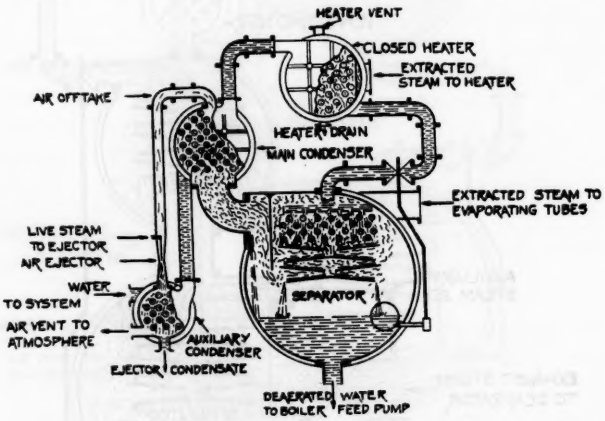

FIGURE 6—EXTRACTION STEAM DEAERATOR.

plied with steam at a temperature slightly above the water temperature in the vacuum space of the separator, a part of the water evaporated, and dissolved gases liberated. Incoming feed water passes through the air ejector after condenser, the vent condenser, a closed feed heater supplied by extraction steam, and into the

separator shell. In the separator, the feed is distributed over a nest of coils also supplied with extraction steam, and over a series of flat trays. The air ejector removes vapors and dissolved gases. Vapor is condensed in the vent condenser and flows back into the separator while air and non-condensible gases are discharged to atmosphere at the air ejector after condenser. Feed pump suction of the deaerated water is obtained at the bottom of the separator as in the previous types.

The Frontispiece represents a widely used deaerator and provides a cutaway sectional view to clearly illustrate its construction. A parallel down flow principle for both water and heating steam is employed. Water after passing through the vent condenser is rained through a maze of steam distributing jets, drops to a nest of heating trays, flows downward to a second nest of air separating trays where dissolved gases are released, and finally accumulates in the bottom of the tray compartment and the storage reservoir. It will be noted that the vent suction to vent condenser is located near the bottom of the tray compartment as contrasted to vent discharge at the top of previously described heaters.

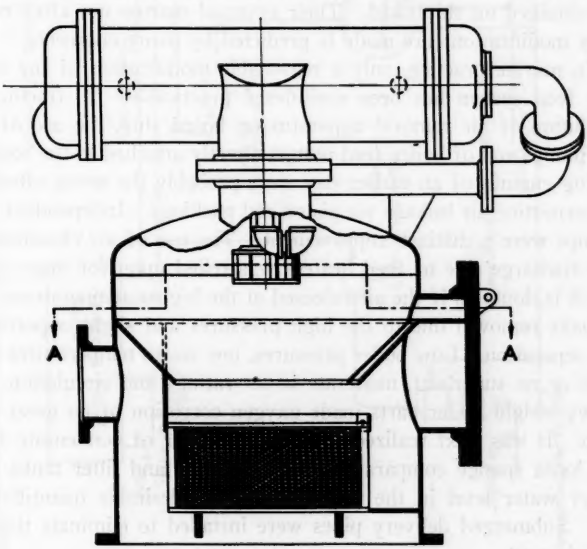

FIGURE 8—MARINE JET TYPE DEAERATOR.

Tray heaters of the type described above are not usually considered satisfactory for marine use where pitching and rolling may interfere with the desired water distribution. Spray heaters have been recently developed for marine application and a heater of this type is shown in Figure 8. Incoming feed passes through a large vent condenser and is distributed into the shell by a spray nozzle proportioned to produce a large exposed area of thin water sheets. Exhaust or other heating steam is first passed through a bank of deaerating elements, then rises upward with the liberated gases and next performs the function of heating the water spray in the nozzle chamber. Steam in sufficient quantity to remove with it all liberated non-condensible gases flows into the vent condenser located on top of the apparatus.

SHIPBOARD APPLICATION.

Heaters of the above deaerator types have not been generally utilized in Naval and Marine applications because of excessive weight and space requirements and also due to the fact that a sufficient hydrostatic head to the main feed pump suction cannot readily be obtained on shipboard. Their eventual marine use after necessary modifications are made is predicted by many engineers.

In marine practice, only a reasonable modification of the existing feed system has been considered practicable. In tracing the evolution of air removal apparatus on board ship, the use of wet air pumps and of boiler feed pumps directly attached to the reciprocating engines of an earlier day were probably the worst offenders in permitting air leakage via piston rod packings. Independent feed pumps were a distinct improvement. The use of air chambers on the discharge side of feed heaters was relied upon for many years but it is doubtful if the air released at the higher temperatures was actually removed due to the high pressures and slight opportunity for separation. Low boiler pressures, low steam temperatures with little or no superheat, moderate boiler ratings and circulation, and heavy weight boiler parts made oxygen corrosion of no great concern. It was next realized that the spill over of condensate from the loofa sponge comparatments of the feed and filter tanks to a lower water level in the tank entrained undesirable quantities of air. Submerged delivery pipes were installed to eliminate this air entrainment.

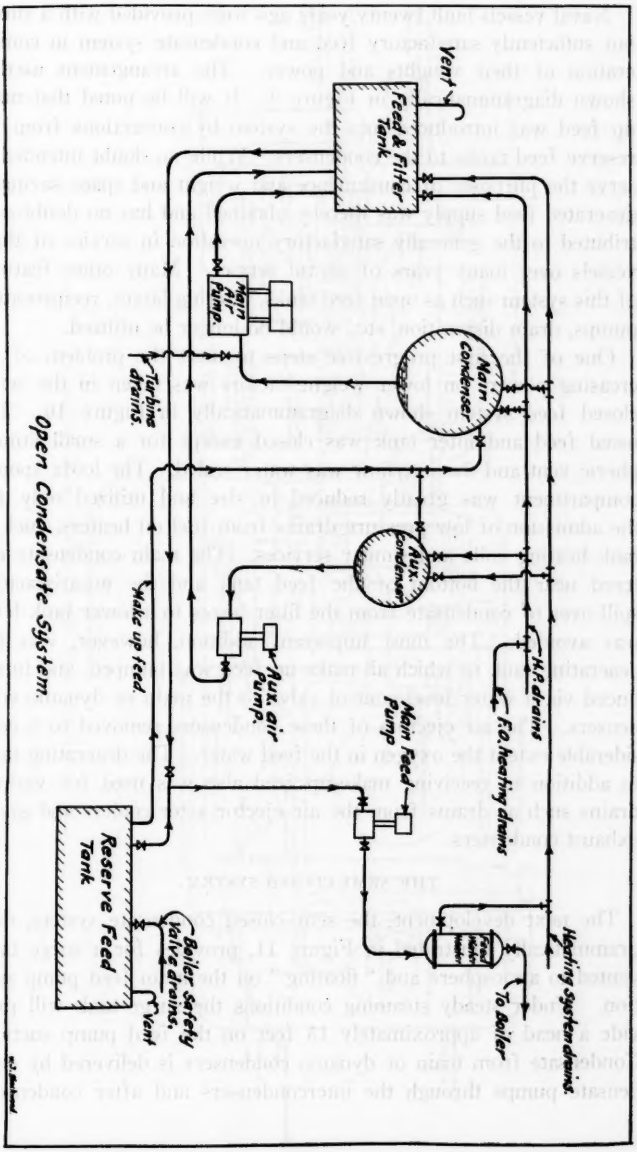
Vent
Feed & Filter Tank
Main Air Pump
Main condenser
Turbine drains
Aux. condenser
Make up feed
Aux. air Pump
H.P. drains
F.O. heating drains
Main Feed Pump
Heating System drains
To Boiler
Reserve Feed Tank
Boiler safety valve drains
Vent
Open Condensate System.

FIGURE 9.

Naval vessels built twenty years ago were provided with a simple but sufficiently satisfactory feed and condensate system in consideration of their weights and power. The arrangement used is shown diagrammatically in Figure 9. It will be noted that make up feed was introduced into the system by connections from the reserve feed tanks to the condensers. While no doubt intended to serve the purposes of convenience and weight and space saving, a deaerated feed supply was thereby obtained and has no doubt contributed to the generally satisfactory operation in service of these vessels over many years of useful service. Many other features of this system such as open feed tanks, filtering boxes, reciprocating pumps, drain disposition, etc., would no longer be utilized.

One of the first progressive steps to meet the problem of increasing powers on lower weight factors was taken in the semi-closed feed system shown diagrammatically in Figure 10. The usual feed and filter tank was closed except for a small atmospheric vent and the overflow was water sealed. The loofa sponge compartment was greatly reduced in size and utilized only for the admission of low pressure drains from fuel oil heaters, fuel oil tank heating coils and similar services. The main condensate entered near the bottom of the feed tank and the unsatisfactory spill-over of condensate from the filter boxes to a lower tank level was avoided. The most important addition, however, was the deaerating tank to which all make-up feed was pumped, and introduced via a water level control valve to the main or dynamo condensers. The air ejectors of these condensers removed to a considerable extent the oxygen in the feed water. The deaerating tank in addition to receiving make-up feed also was used for various drains such as drains from the air ejector after coolers and gland exhaust condensers.

THE SEMI-CLOSED SYSTEM.

The next development, the semi-closed condensate system, diagrammatically illustrated in Figure 11, provides for a surge tank vented to atmosphere and "floating" on the main feed pump suction. Under steady steaming conditions the surge tank will provide a head of approximately 15 feet on the feed pump suction. Condensate from main or dynamo condensers is delivered by condensate pumps through the intercondensers and after condensers

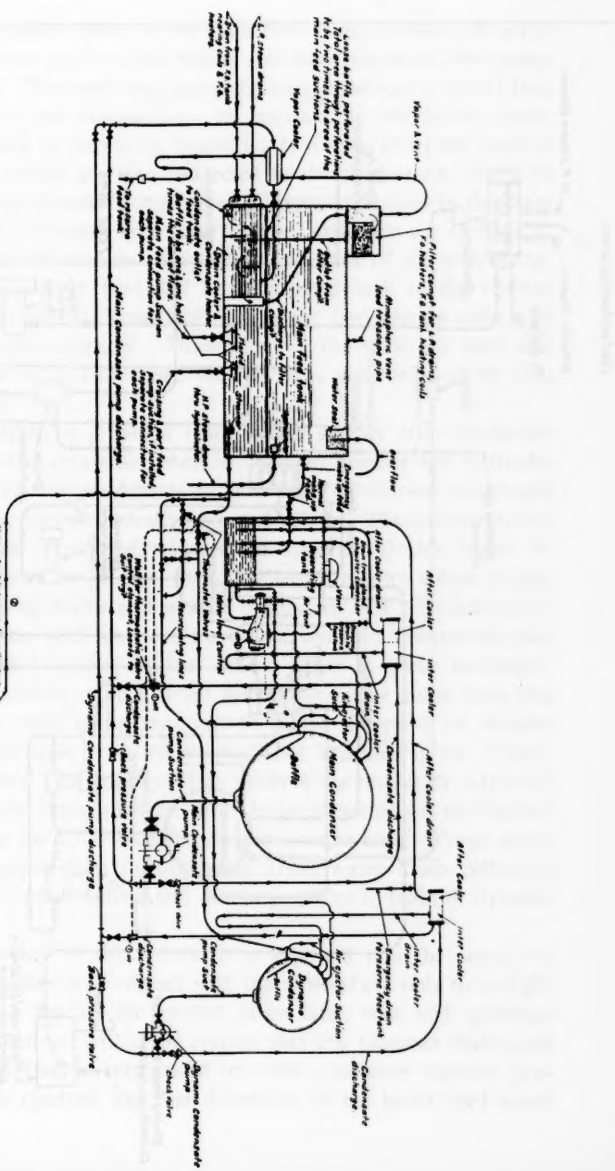

FIGURE 10—EARLY SEMI-CLOSED FEED SYSTEM.

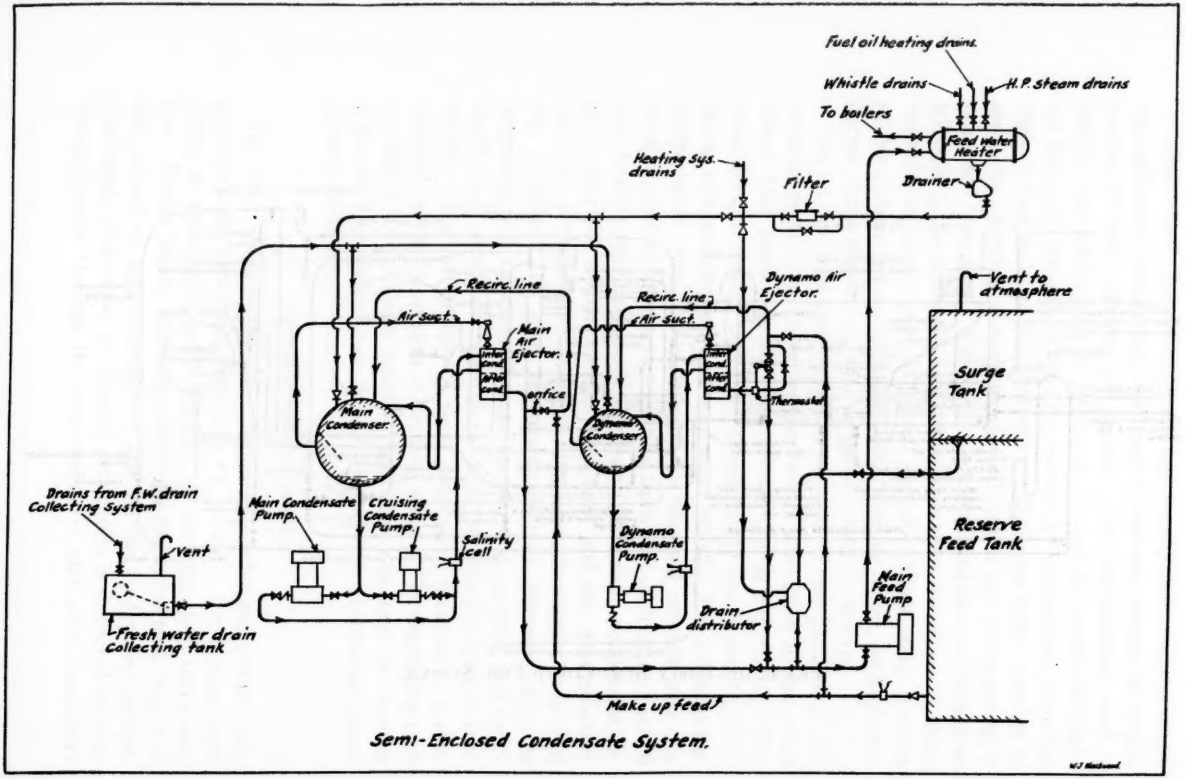
Fuel oil heating drains.
Whistle drains
H.P. Steam drains
To boilers
Feed Water Heater
Heating Sys. drains
Filter
Drainer
Recirc. line
Air Suct.
Main Air Ejector.
Recirc. line
Air Suct.
Dynamo Air Ejector.
Vent to atmosphere
Surge Tank
Main Condenser.
Dynamo Condenser.
Thermostat
orifice
Drains from F.W. drain Collecting System
Vent
Main Condensate Pump.
Cruising Condensate Pump.
Salinity cell
Dynamo Condensate Pump.
Reserve Feed Tank
Main Feed Pump
Drain distributor
Fresh water drain Collecting tank
Make up feed
Semi-Enclosed Condensate System.

FIGURE 11.

of the air ejectors direct to the main feed pump suction. A surge tank connection and various drains join into this main feed pump suction line. The main feed pump discharges through a closed feed water heater and economizers, if installed, to the boiler drum. Make up feed in necessary quantities is drawn from the reserve feed tanks, which are also connected to the surge tank, direct to either main or dynamo condensers. Oxygen contained in the main feed supply is thereby extracted by the condenser air ejectors at its entry into the system. Any water in excess of the amount required for make-up feed will be discharged back to the reserve feed tank through the condensate pump, the feed suction main, and the surge tank overflow. Deaeration of the make-up feed and maintenance of a full surge tank is thus accomplished by this arrangement.

Bypass piping is provided from the air ejector after condenser to its respective condenser shell in order to provide for recirculation of the cooling condensate at light loads by manual valves and orifices or by thermostatically operated valves. The various drains also comprise a part of this related system. Drains under 35 pounds pressure or greater, including high pressure steam drains, fuel oil heating drains and whistle drains are first introduced into the feed heater shell and lead via a float control automatic drainer plus the added heating system drains either to main condenser, dynamo condenser or to a drain distributor in the surge tank line to the main feed pump suction. A motor driven drain booster pump is sometimes provided although not indicated in the Figure. The main feed pump suction thus receives the combined output of the condensate pump plus the drain booster pump plus the balancing effect of the hydrostatic head of the surge tank. Fresh water drains are piped to a float-operated fresh water drain collecting tank vented to atmosphere and discharge either to main or dynamo condensers.

From a study of this system it is apparent that the supply of boiler feed water is in contact with the atmosphere only to a slight extent in the top of the vented surge tank, that high pressure drains are enclosed within the system, that low pressure drains and all make up feed is introduced into the condenser vacuum produced by air ejectors, and that deaeration of the boiler feed water

FIGURE 11.

is accomplished to a reasonable extent without much additional equipment or complexity in operation.

THE CLOSED SYSTEM.

The closed feed system is the latest development for shipboard use and is diagrammatically illustrated in Figure 12. This system is of the entirely enclosed type and at no point in the system is a free water surface exposed to the atmosphere. Condensate from the main or dynamo condensers is discharged by condensate pumps to the surface of an elevated closed surge tank which is maintained at condenser vacuum by connecting vent lines to the condenser. By the combination of high vacuum on the water surface and a sufficiently high temperature of the water a continuous ebullition is obtained. The mixture of steam and air is drawn into the condenser shell from which the air ejectors eventually expel the air and non-condensible gases to the atmosphere. Condensate booster pumps take their suction from the bottom of the surge tank and discharge at about 85 pounds pressure through the air ejector inter and after condensers and through a closed feed water heater to the main feed pump suction. The condensate booster pump is in reality a first stage of the main feed pump. The main feed pump discharges through a boiler economizer to the boiler drum. Make up feed is introduced into the system by connecting lines to main or dynamo condensers or to the surge tank. Normally this make up feed is drawn into the condenser in order to receive as complete and thorough deaeration as possible before introduction into the surge tank where it receives further deaeration. During operation, the surge tank level can be adjusted without loss of vacuum by passing excess feed to the reserve feed tank not otherwise connected to the surge tank by a three-way valve on the dynamo booster pump discharge, not shown on drawing, or by admitting more feed to the condensers.

A bypass arrangement, thermostatically controlled, is provided from the air ejector after condenser to its respective condenser in order to provide for a sufficient recirculation of cooling condensate at light loads or low powers.

High pressure drains, heating system drains and whistle drains are introduced into the feed heater shell and lead via an automatic

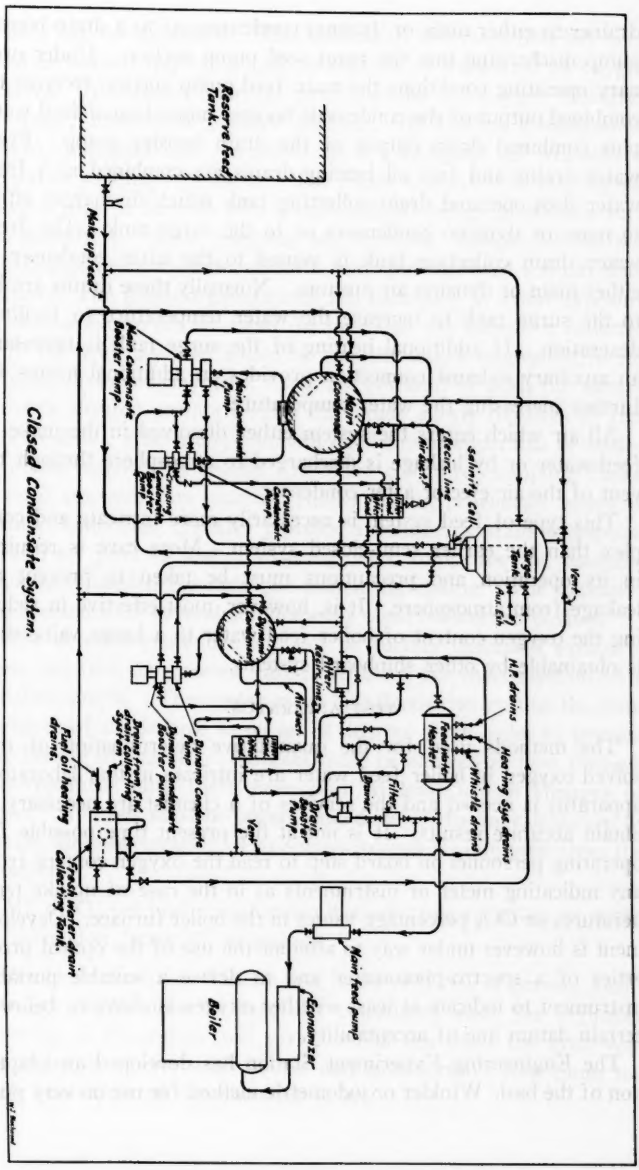
Reserve Feed Tank.
Make up feed
Closed Condensate System.
Main condensate Booster Pump.
Main Condensate Pump.
Main Condenser
Air ejector
Circulating Pump
Circulating Booster Pump
Salinity Cell
Electric Line
Surge Tank
Vent
Dynamo Condenser
Air ejector
Dynamo Condensate Booster pump.
Drains from Evt. drain collecting System
Fuel oil heating drains.
Fresh water drain collecting Tank.
Dynamo Condensate Pump
Vent
Feed water Heater
Filter
Drains
Feed Water Booster Pump.
H.P. drains
Whistle drains
Heating Syst drains
Main feed pump
Economizer
Boiler

FIGURE 12.

drainer to either main or dynamo condensers or to a drain booster pump discharging into the main feed pump suction. Under ordinary operating conditions the main feed pump suction receives the combined output of the condensate booster pump heated feed water plus combined drain output of the drain booster pump. Fresh water drains and fuel oil heating drains are combined in a fresh water float-operated drain collecting tank which discharges either to main or dynamo condensers or to the surge tank. The fresh water drain collecting tank is vented to the after condenser of either main or dynamo air ejectors. Normally these drains are led to the surge tank to increase the water temperature to facilitate deaeration. If additional heating of the surge tank is necessary, an auxiliary exhaust connection provides an additional means for further increasing the water temperature.

All air which enters the system either dissolved in the make-up feed water or by leakage is discharged to atmosphere through the vent of the air ejector after condenser.

This type of feed system is necessarily more intricate and complex than the earlier semi-closed system. More care is required in its operation and precautions must be taken to prevent air leakage from atmosphere. It is, however, most effective in reducing the oxygen content of boiler feed water to a lower value than is obtainable by other shipboard systems.

TEST APPARATUS.

The methods used for the quantitative determination of dissolved oxygen in boiler feed water are intricate in that laboratory apparatus is needed and the services of a chemist are necessary to obtain accurate results. It is not at the present time possible for operating personnel on board ship to read the oxygen content from any indicating meter or instruments as in the case of uptake temperatures or CO_2 percentage values in the boiler furnace. Development is however under way to attempt the use of the optical properties of a spectro-photometer and to devise a suitable portable instrument to indicate at least whether oxygen is above or below a certain datum line of acceptability.

The Engineering Experiment Station has developed an adaptation of the basic Winkler or iodometric method for use on very pure

waters and on shipboard. This method of determination has been used on several ships to obtain an analysis of the extent of oxygen present. It is based upon the principle that the oxygen dissolved in water, when in an alkaline medium, will oxidize a manganous salt to a manganic salt. In acid solution a manganic salt will oxidize an iodide yielding free iodine. The iodine equivalent to the original oxygen may be titrated with a standardized reducing solution such as thiosulfate. Four reagents are required, manganous sulfate, alkaline potassium iodide, sulfuric acid, and standard sodium thiosulfate. The greatest precautions are necessary to avoid exposure of the sample to the air from the time that the sample is collected until the acid has been added to free the iodine equivalent to the original dissolved oxygen. After the addition of acid, the sample must be titrated promptly since the iodide slowly oxidizes to free more iodine. Also a large amount of chemical apparatus is needed to insure satisfactory results. A cooler coil, three sampling flasks, several stoppered tip pipettes, rubber tubing previously boiled in sodium hydroxide, transfer pipettes, a volumetric transfer pipette, measuring pipettes and a titrating flask comprises the essential equipment needed for only one measuring station. The extensive requirements for several simultaneous observations are obvious.

The detailed procedure will not be further described except to point out that the greatest care is required for the collection of a reliable sample. The cooler must be effective to reduce the temperature of the sample to 60 or 70 degrees F. in order to prevent any boiling or flashing. Samples must be allowed to flow through the apparatus until there have been at least fifteen changes of water. Analysis must be begun immediately. In the calculation of results the concentration of dissolved oxygen is computed from the equation

Ml. of O_2 per liter = difference between two titrations $\times$ 0.223 $\times$ correction factor of thiosulfate.

While the modified Winkler test is the only one at present available, its results must be carefully considered since the improper drawing of the sample will give a result ten times too great and the inclusion of one small bubble may give a result four times too high when the true concentration is low.

SHIPBOARD TESTS.

Chemical engineers from the Engineering Experiment Station have conducted oxygen content surveys on several recently commissioned destroyers and cruisers. Earlier experimental work involved many difficulties but a workable procedure has been evolved and further tests under actual service conditions are scheduled as opportunity permits.

During one of the early shipboard determinations on a destroyer fitted with a semi-closed feed system the following average determinations were obtained from four samples:

Sample No.	Location	ml.O_2/L
1	Port feed line, 1st sample	0.467
2	Port feed line, 2d sample	0.390
3	Starboard feed line, 1st sample	0.089
4	Starboard feed line, 2d sample	0.378

The above results were not entirely self consistent and suggest a possibility of air contamination during sampling and analysis, with all errors positive or in excess of the true value.

Similar tests were also conducted on the semi-closed feed system of a recent cruiser. From general averages of all the analytical results it appeared that the main feed water carries into the boiler about 0.4 milliliters of oxygen per liter of water. The main feed pump suction contained about twice this amount of oxygen and the drain booster pump discharge had over three times the amount in the feed to the boilers. The concentration of dissolved oxygen in the water in the surge tank was between five and six times that of the main feed water or about 2.2 milliliters per liter.

The results from the twenty-five determinations indicated that a wide variation in the oxygen content existed at the several sampling locations. For example, the main feed varied from less than 0.2 milliliter per liter to 0.8 milliliter per liter. The drain booster pump discharge varied from 0.26 milliliter to about 2.4 milliliters per liter. Apparently erratic results may be expected where the oxygen content of the water being sampled varies continuously.

A series of shipboard tests were next conducted on a destroyer fitted with a closed feed system. Measurements were made with improved apparatus and results were carefully checked. Attempts

were made to use an Electron Beam Sectrometer in lieu of a starch indicator with the sodium thisulfate solution but satisfactory results were not obtainable. With five questionable determinations eliminated, the average oxygen determinations at each of four sampling locations was calculated to be as follows:

Location	Average ml.O_2/L	No. of determinations.
Starboard main feed	0.27	22
Port main feed	0.11	17
Starboard booster pump discharge	0.54	4
Port booster pump discharge	0.22	5

It will be noted that for both starboard and port systems the water from the booster pump discharge line contained twice as much oxygen as the same water after it had passed through the feed heaters and the feed pump. This indicates that approximately half of the oxygen originally present in the feed water as it leaves the surge tank disappears before the water reaches the boiler. If only the periods when concurrent samples were being taken from all four locations are considered, the reduction is even more striking. These comparative values are:

Location	Average ml.O_2/L	No. of determination in average value
Starboard main feed	0.24	9
Starboard booster pump discharge	0.54	4
Port main feed	0.08	5
Port booster pump discharge	0.22	4

An attempt was made to establish a correlation between the temperature and pressure conditions in the feed system and the concentration of dissolved oxygen in the boiler feed water. The only suggestion of a correlation which was obtained from these data was that the dissolved oxygen concentration decreases as the temperature and pressure in the surge tank increases. An apparent inverse relationship which existed between condenser pressure (pressure at condensate pump suction) and oxygen content was meaningless, because the discharges from both port and starboard condensers merge and are mixed in the surge tank.

The concentration of dissolved oxygen in this destroyer closed system test ranged between a minimum of 0.03 and a maximum approaching 1.0 milliliters per liter. The average of thirty-nine determinations was 0.19 milliliters. The oxygen content of the feed water was also found to decrease gradually with prolonged steaming under way. Conversely upon resumption of at-anchor conditions, the oxygen content of the boiler feed water increased. A difference in oxygen content between starboard and port manifold indicated that some air leakage into the starboard system accounted for the high values of oxygen content. In all of the tests cited it was impossible to make a truly comprehensive survey of the distribution of dissolved oxygen because all but the feed lines were under a vacuum from which samples could not be withdrawn.

COMPARISON OF TYPES.

In comparing a semi-closed feed system with a closed feed system, it appears that average concentration of dissolved oxygen in boiler feed water in a semi-closed system is approximately twice that measured in the closed system. However, the closed feed system, which in its virtual entirety is maintained under the maximum attainable vacuum, is susceptible to contamination by infiltration of air through leaks in the piping. The long path which the separated air must travel to the after cooler would prevent its rapid rejection from the system. The semi-closed system offers some reduction in weight and space and provides a greater simplicity in piping, equipment and operation.

SUPPLEMENTARY CHEMICAL TREATMENT.

Present central station practice demands practically zero oxygen in the boiler feed water, although values of 0.02 to 0.03 milliliter per liter is sometimes permitted. In such cases a supplementary chemical treatment of sodium sulfate, tannin, or other oxygen reducing chemical may be employed. The Navy Boiler Compound 1933 contains by weight the following percentages of ingredients:

Anhydrous sodium carbonate (NA_2CO_3)	44 per cent
Anhydrous disodium phosphate (NA_2HPO_4)	47 per cent
Cornstarch	9 per cent

It is possible that even the relatively small percentage of corn starch might have an oxygen reducing property, although this characteristic has not been definitely established.

Chemical reduction could be used in the Navy, but its use does not appear to be desirable. Sodium sulfate is the least expensive and most specific chemical and would probably be resorted to if this method were adopted. The necessary and relatively difficult determination of sulfate would complicate the present simple system of boiler water control. The carrying of a large amount of additional chemicals in ships stores would also be undesirable. The necessary sulfate could not easily be included in the boiler compound since the sulfate requirement alone would amount to from two to ten times the quantity of boiler compound now used. The large amount of sulfate would also increase the total dissolved solids in the boiler water. This feature might induce priming unless excessive blowdowns were employed.

CONCLUSION.

It appears that efforts to reduce the dissolved oxygen content of boiler feed water to a maximum of 0.10 milliliter per liter will be productive of most beneficial results. While remarkable progress has already been made, improvement and further development is needed to make the interrelated feed, condensate, and drain systems more effective in supplying boiler water of minimum dissolved oxygen content. It is evident that test results on shipboard show in most cases a concentration in excess of desired values. A simple and accurate method for oxygen measurement for shipboard use is invaluable to progress. The utilization of some features of central station equipment may be found practicable provided simplicity, compactness and ease of operation is not impaired. The desired degree of deaeration may require the adoption of a fully closed feed system, although it might be attained by some revision of the semi-closed system or other modified equipment. Improvements may be expected by the segregation of all drains and the continuous withdrawal of a small amount of water from near the surface of the surge tank to the condenser fitted with air ejectors. When the normal oxygen content can be reduced to 0.1 milliliter per liter, it may then only be desirable to revise the Navy

Boiler Compound to include some ten or twenty per cent of sodium sulfate to ameliorate the effect of the residual oxygen. While recent modern requirements demand an exceptionally low oxygen content, it is believed that with progress already attained and with prospective improvements contemplated, a useful service life of twenty years or more for boilers and associated equipment can be satisfactorily achieved.

NOTE:—Acknowledgements for various material in this article are made to the Elliott Company; The Cochrane Corporation; The Bethlehem Shipbuilding Corporation; Mr. R. C. Adams, Chemical Engineer, Engineering Experiment Station, and Mr. W. J. Blackwood, Marine Engineer, Bureau of Engineering.

ALTERNATING CURRENT MOTORS CONTROLLED BY MUTATORS.

By Rear Admiral S. M. Robinson, U. S. Navy, Member.*

This is the second of a series of three papers dealing with the use of electron tubes for power purposes coming from the pen of Admiral Robinson. His many friends who watch for his contributions will be glad to hear that he is now quite completely recovered from injuries received in an automobile accident about two months ago. His first paper dealt with "Direct Current Power Transmission." This paper covers power utilization, and the third paper will show how to make some of the calculations covering a number of the circuits used. The author suggests that perhaps the title used for these three papers should have been "New Electricity," because the ability of the electron tube to start and stop currents in practically any desired time has opened up an entirely new method of utilizing electricity; the method is so novel, and brings in so many new concepts, that it is almost as if a new form of energy had been discovered.

The use of the electron tube for communication purposes has been such a rapidly developing art that it has absorbed practically all the attention of the electrical engineers up to now, but recently some of these engineers have turned their attention to the power field, and the research already conducted has opened up wonderful possibilities along that line. The use of direct current for power transmission is one and the development of new types of alternating current motors is another.

The essential parts of one of these motors are shown in Figures 1 and 2. This type is called the "thyratron motor" because it was first used with thyratron tubes forming the mutator; this is a rather unfortunate choice of a name for the motor, as it is probable

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that some other type of electron tube will be used with it, especially in the larger sizes. Any one of the various types of vapor filled electron tubes, fitted with a control device, is suitable for the mutator of this motor. The tube shown in the sketch, Figure 2, is a thyratron. The Naval service is familiar with this tube since it has extensive use on board ship. It is an evacuated tube, filled with mercury vapor, and provided with an anode, a control grid, and a hot cathode.

The motor, shown in Figure 1, is similar to a synchronous motor; it has a stationary armature and a revolving field. The armature is divided into two halves, electrically, but the windings are placed in the same slots of the core to form one armature. The field is interposed, electrically, between the two halves of the armature. Current is conducted to and from the revolving field by two slip rings.

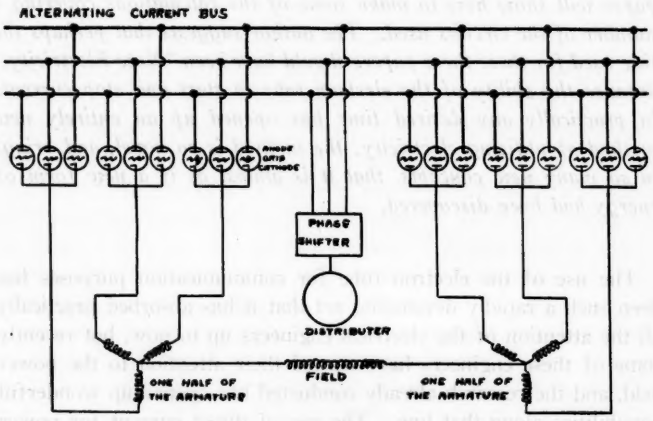

FIGURE 1.

The mutator, for controlling the motor, consists of 18 thyratron tubes, together with a phase shifter and a distributor and the necessary small transformers and rectifiers which will be described in detail later. The name "mutator" has been selected for this apparatus because it performs, for this motor, the same functions as the commutator of a direct current motor.

It will be noted that the tubes are arranged in groups of three; one tube of each group connects to a phase of the supply bus and the three tubes connect to one phase of the motor. It will also be noted that the nine tubes on one side have their anodes and cathodes connected in a reverse direction from the nine on the other side; this is necessary since the current flows from the tubes on one side, through the motor, and back through the tubes on the other side.

In Figure 2, we see that the phase shifter is supplied with current from the main alternating current bus, through a transformer, which steps down the voltage to the desired amount; the current goes from this transformer to the primary of the phase shifting transformer which is either a selsyn motor or an induction motor; the rotor of the motor is the secondary of the phase shifting transformer; the rotor can be clamped in any desired angular position and will thus regulate the phase angle between the e.m.f. of the secondary of the phase shifter (and hence of the grid which it supplies) and the e.m.f. of its primary (and hence of the main bus and also the anode of the tube); in this manner, we can obtain any desired phase relation between the e.m.f.'s of the grid and the anode.

After leaving the phase shifter, the current next passes through another transformer on its way to the distributor; this transformer has a 3-phase primary and a 6-phase secondary, or rather, each phase of the secondary is divided at its middle point; this makes it possible to have the direction of current flow the same in all the brushes which is desirable for reasons to be explained later.

From the transformer, current next passes to the distributor which is mounted on the motor shaft, and consists of two rings with six brushes on one ring and one brush on the other ring. The ring with one brush is connected, electrically, to one segment of the other ring (shown shaded in the Figure); the remainder of the segments of this second ring are disconnected, electrically, from each other and from the live segment. For a 2-pole motor, there must be a brush for each phase of each half of the motor, making six in this case. The distributor shown is for a 2-pole motor; with any greater number of poles and with one live segment, the number of brushes will be $\frac{p}{2}$ times six where p represents the number of

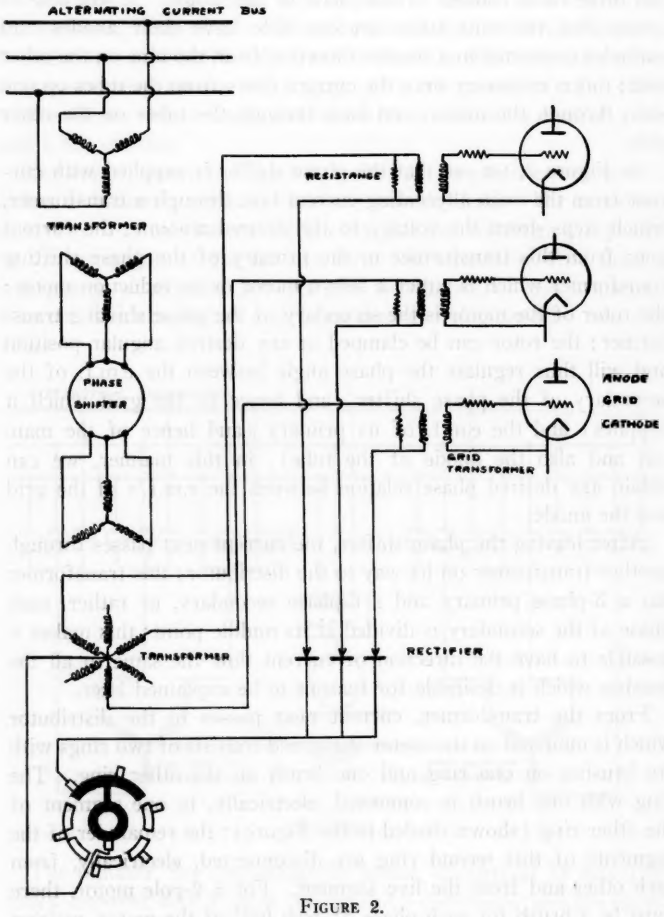
ALTERNATING CURRENT BUS
TRANSFORMER
PHASE SHIFTER
TRANSFORMER
RESISTANCE
ANODE
GRID
CATHODE
GRID TRANSFORMER
RECTIFIER

FIGURE 2.

poles; if it is desired to use more than one live segment, the number of brushes may be decreased directly as the segments are increased; one is the minimum number of live segments that can be used.

The purpose of the distributor is to insure the excitation of the "proper tube," and it does this by interrupting the grid circuits of all other tubes; the "proper tube" is the one which will pass current to the phase of the motor which is in position to produce torque in the desired direction.

After current has passed through the distributor, it then goes through the primary of the grid transformer which completes the circuit.

The connection between the distributor and the grid transformer is interrupted by a rectifier. This rectifier serves three purposes. First, it makes it possible to connect the grid transformers of all tubes connected to one motor phase (three in this case) to the same brush, thus making it possible to use six brushes and two rings instead of eighteen brushes and four rings. (These rings are, of course, in addition to the two rings which are necessary for carrying the load current to and from the revolving field.) If the three grid transformers in one group of tubes were connected to one brush, without the interposition of rectifier, then all three of them would be excited all the time and the control would be ineffective. Second, it suppresses the negative loop of the sine wave so that, when the circuit is broken by the brush of the distributor, there will never be any possibility of a positive inductive kick which might be of sufficient value to fire the tube. Third, the rectifier makes it possible to connect each brush so that current will always flow in such a direction that it will not pit the segments of the distributor but will confine this action to the brushes where the effect is not deleterious.

There is a resistance across the terminals of the primary of the grid transformer; its function is to reduce the arcing effect, due to the reactance of the transformer, when the circuit is interrupted by the distributor.

From the above description of the circuits of Figure 2, it will be seen that the control of the voltage, imposed on the grid of any tube, is divided between the phase shifter and the distributor. For example, the phase shifter may be in such a position that it would

cause a certain grid to allow its tube to fire, but it can not do so unless the grid connection is completed through the brushes on the distributor, and this can happen only when the proper brush is on the active segment of the distributor ring. As stated before, the purpose of the distributor is to insure that only such tubes will fire as will pass current through a phase that is in position to exert torque in the desired direction.

We can now analyze the action of the motor as a whole. It will be noted from Figures 1 and 2, that, for any position of the motor, there will always be two groups of tubes, one group in each half of the mutator, whose grids will be excited when the motor is connected to the bus; each one of these groups will connect to one phase in each half of the motor. The motor design is such that these tubes will each be connected to a phase which is in position to produce torque in the desired direction, when current flows through it and the field. The amount of current that will flow will depend on the position of the phase shifter; if this is retarded (out of phase with the supply e.m.f.) by any amount less than 90 degrees, then a current will flow through the motor and produce a torque to start the motor. With the motor in the stopped position, the tubes simply act as rectifiers and pass direct current through the motor. Due to the torque exerted, the motor will begin to revolve and as it does so, a new brush will come onto the active segment of the distributor, and this will cause the grid of one of the tubes of another group to be fired; this action will pass current through another phase of the motor; the current in the first phase will drop to zero as soon as the e.m.f. imposed on its conducting tube falls to zero. Of course, the design of the motor is such that, as each new phase receives current, it is always in position to produce torque in the proper direction. It will be noted that current flows, first through a phase of one-half of the armature, then through the motor field, then through a phase, or phases, of the other half of the armature and back to the bus and, that the current shifts, in succession, from one phase of the motor to another.

As long as the torque of the motor exceeds that of the load, the motor will accelerate. When the two torques are equal, the motor speed will become constant. To obtain further increase of speed, it will be necessary to change the setting of the phase shifter. As

the phase angle between anode and grid is reduced, the motor speed will be increased, since higher voltages will be imposed on the motor, and a higher speed will be necessary to develop sufficient counter e.m.f. to balance the higher voltage.

As the motor speed is increased, the counter e.m.f. developed by the motor will increase until, finally, a point will be reached where the motor counter e.m.f. will be sufficient to automatically shift the current from one group of tubes to another (and thus from one motor phase to another) at the proper time, just as the counter e.m.f. in a direct current motor shifts the current from one armature coil to another and hence from one bar of the commutator to another. This speed of the motor is about one-quarter speed; as stated before, until this speed is reached, the commutation is performed by the e.m.f. of the supply bus.

Since the tubes are supplying the motor with direct current, the speed of the motor will be independent of the frequency of the supplied e.m.f. and will be limited only by the design of the motor itself.

It is now desirable to compare the simultaneous action of the two halves of the mutator (the two banks of nine tubes). As stated before, the two sides of the mutator are controlled by the same phase shifter and, therefore, the grids on each side will be excited at the same point on the sine wave. However, at a given moment, current from any one of the three phases of the supply bus, may be flowing in a phase of the left half of the motor, through one of the three tubes connected to it and after flowing through the field and through a phase of the second half of the motor, the current in this phase may flow through either of the two tubes connected to that phase and also connected to the two remaining phases of the supply bus. Thus it will be seen that the corresponding tubes in the two halves of the mutator do not necessarily pass current at the same time and that the combinations of tubes, from moment to moment, will be changing.

We will now study in detail the action of the mutator. In the previous paper on "Direct Current Power Transmission," the phenomena of "rectification" and "inversion" were discussed in detail so, it will not be repeated here. In the case under discussion we have "rectification" and, while we do not have "inversion"

under that name, we do have "commutation," which is exactly the same thing. The changing of current from one group of tubes and one phase to another group of tubes and another phase is called "commutation"; actually it gives the equivalent of a half-wave alternating current in each phase of the motor and is equivalent, in all respects, to the phenomenon described in the previous paper as "inversion." However, since we are dealing with a motor, the term "commutation" will be better understood and will be used to describe the action of the tubes. The two phenomena, "rectification" and "commutation," take place in the same tubes. This can best be understood by replacing the mutator circuit by an equivalent circuit, where separate sets of tubes are used for the two functions. Such a circuit is shown in Figure 3. Here the current is first rectified, then passed through

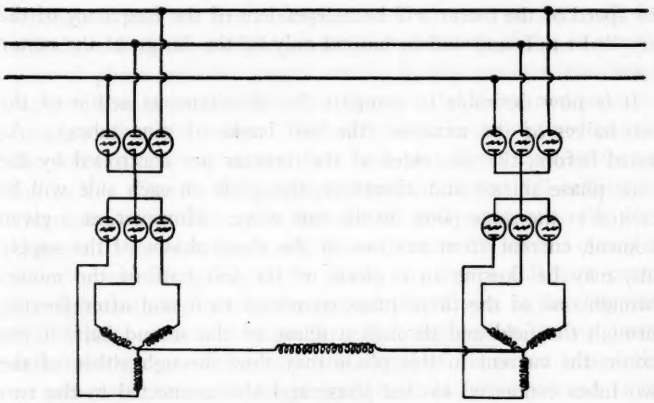

FIGURE 3.

the commutator tubes, then through the first half of the motor, then through the motor field, then through the second half of the motor, and then through the commutator and rectifier tubes back to the bus. The grids of the rectifier and commutator tubes can be controlled independently, so as to give proper speed control and, also, proper commutation. However, such an arrangement does not give any means of starting the motor because there is no commutating voltage either at the low speeds or the stopped condition;

as explained above, this commutating voltage is supplied by the supply bus for the motor shown in Figure 1. The motor shown in Figure 3, will run satisfactorily, after it reaches about ¼ speed, when it will have sufficient counter e.m.f. for commutating purposes. Also, the arrangement shown in Figure 3, does not give the most economical use of the tubes themselves; in Figure 3, we have 12 tubes, and in Figure 1, we have 18 tubes. However, each of the tubes in Figure 3 must carry three times as much current as the tubes in Figure 1. However, the main objection to the arrangement shown in Figure 3 is that such an arrangement, as stated above, does not provide satisfactory commutation at standstill and low speeds.

There is one other point that should be noted in regard to the commutation of this motor. In a direct current motor, we generally shift the brushes off neutral, in order to provide a greater counter e.m.f. for reversing the direction of current in the coil being commutated; we do exactly the same thing with a thyratron motor; the brushes of the distributor are advanced through a certain angle to provide the necessary counter e.m.f. for commutation; this angle of advance will be about 30 degrees and it will give satisfactory commutation at all loads and speeds; in this respect it differs from the direct current motor; the reason for this is that an excess brush shift, in this motor, will not stop commutation, but will be reflected in the operating characteristics of the motor; therefore a position can be found which will give satisfactory commutation at all speeds and loads. The angle of advance can not, however, be reduced below a certain minimum, because the tubes are acting as inverters and must carry a current which leads the e.m.f. (in this case of the motor) as was explained in the previous paper.

From the description of the motor already given, it will be seen that this motor has all the characteristics of a series direct current motor. The speed is a function of the load imposed on it. However, it has certain advantages over the direct current motor. Its speed can be controlled without wasting any power in resistance. The speed can be controlled by the phase shifter, which changes the power factor of the supplied power and, therefore, wastes no power; it does, of course, produce wattless current but this can be compensated for in various ways. This type of motor will be suit-

able for such loads as circulating pumps, blowers, etc., where it is desirable to have variable speed but where the load at each speed is a constant.

This motor has all the advantages of both alternating current and direct current motors, as they are at present. It has the rugged construction of an alternating current motor, with its stationary armature and revolving field; its speed control can be extended by using a transformer, with taps for various voltages thus keeping down the amount of power factor reduction; by using power factor control the wasteful use of resistance is avoided; it has the heavy starting torque of a direct current motor; it has as wide a range of speed control as does the direct current motor; and it has the advantage over both types, that it can be reversed without disturbing the main leads; to reverse the motor, it is only necessary to rotate the position of the brushes of the distributor through 180 degrees, less twice the angle of advance. As to weight and space, it will be better than a direct current motor, and also better

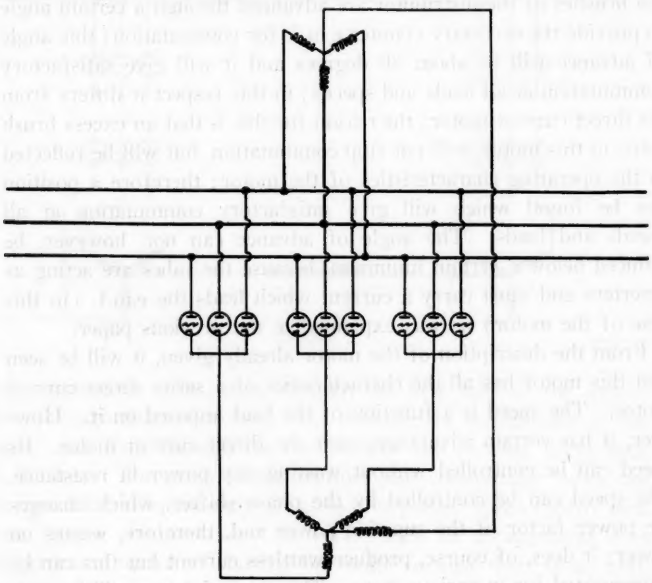

FIGURE 4.

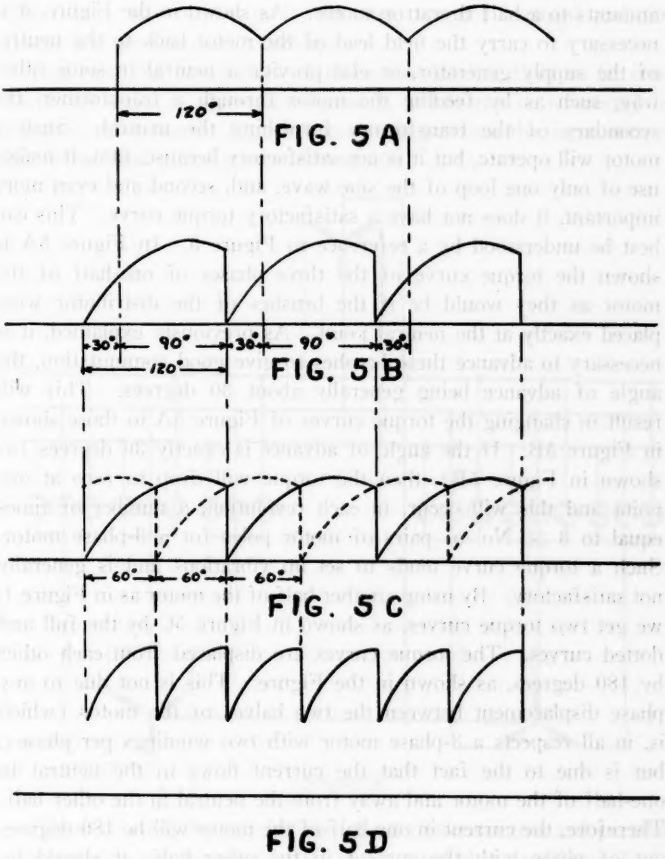

FIG. 5 A

FIG. 5 B

FIG. 5 C

FIG. 5 D

than an alternating current motor, if we provide the latter with sufficient gear to accomplish what the thyratron motor does.

There are many possible variations of the type of thyratron motor shown in Figure 1. There is shown in Figure 4 what amounts to a half thyratron motor. As shown in the Figure, it is necessary to carry the field lead of the motor back to the neutral of the supply generator, or else provide a neutral in some other way, such as by feeding the motor through a transformer, the secondary of the transformer furnishing the neutral. Such a motor will operate, but it is not satisfactory because, first, it makes use of only one loop of the sine wave, and, second and even more important, it does not have a satisfactory torque curve. This can best be understood by a reference to Figure 5. In Figure 5A is shown the torque curve of the three phases of one-half of the motor as they would be if the brushes of the distributor were placed exactly at the neutral point. As previously explained, it is necessary to advance these brushes to give good commutation, the angle of advance being generally about 30 degrees. This will result in changing the torque curves of Figure 5A to those shown in Figure 5B. If the angle of advance is exactly 30 degrees (as shown in Figure 5B), then the torque will drop to zero at one point and this will occur, in each revolution, a number of times equal to 3 $\times$ No. of pairs of motor poles for a 3-phase motor. Such a torque curve tends to set up vibrations and is generally not satisfactory. By using another half of the motor as in Figure 1, we get two torque curves, as shown in Figure 5C by the full and dotted curves. The torque curves are displaced from each other by 180 degrees, as shown in the Figure. This is not due to any phase displacement between the two halves of the motor (which is, in all respects a 3-phase motor with two windings per phase), but is due to the fact that the current flows to the neutral in one-half of the motor and away from the neutral in the other half. Therefore, the current in one-half of the motor will be 180 degrees out of phase with the current in the other half; it should be remembered that, these are motor currents, and that they have motor frequency and not supply bus frequency. This is equivalent to saying that the positive loop of the motor current wave is utilized by the one-half of the motor and the negative loop by the

other half, both developing torque in the same direction. If we plot the torque curves obtained from the two halves of the motor, then we will get the curves shown in Figure 5C. These two torque curves will combine to give the torque curve shown in Figure 5D. This curve has ripples in it, but they are not harmful and the motor will give smooth operation.

However, the two halves of the motor do not have to be connected in series as shown in Figure 1. They can be connected in parallel, as shown in Figure 6, and still produce the same torque curves as shown in Figures 5C and 5D.

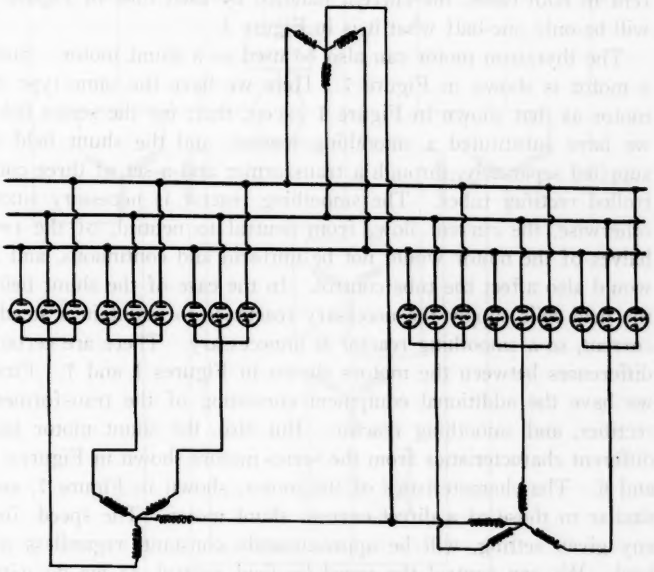

FIGURE 6.

There is one difference between the series-connected and parallel-connected types, however. It will be noted that, in Figure 1, the tubes in the two halves of the mutator are connected in opposite directions, while in Figure 6, both halves are connected in the same direction. This means that, in Figure 1, the current flows to the neutral in one-half of the motor and away from it in the other, while in Figure 6, the current flows to the neutral in both halves.

Therefore, in order to get the torque curves shown in Figures 5C and 5D, with the motor shown in Figure 6, it will be necessary to give a phase displacement between the two halves of the motor, so that it will no longer be a 3-phase motor but will become a 6-phase motor.

With the arrangement shown in Figure 6, the same necessity for providing a neutral exists as in the case of the arrangement shown in Figure 4, but sometimes this is not a handicap. This parallel arrangement is more suitable for the lower voltages where it is necessary to handle large current. Assuming equal total current in both cases, the current handled by each tube in Figure 6 will be only one-half what it is in Figure 1.

The thyratron motor can also be used as a shunt motor. Such a motor is shown in Figure 7. Here we have the same type of motor as that shown in Figure 1 except that, for the series field, we have substituted a smoothing reactor, and the shunt field is supplied separately, through a transformer and a set of three controlled rectifier tubes. The smoothing reactor is necessary since, otherwise, the current flow, from neutral to neutral, of the two halves of the motor would not be uniform and continuous, and it would also affect the tube control. In the case of the shunt field, the field coils supply the necessary reactance to maintain a steady current, so a smoothing reactor is unnecessary. There are certain differences between the motors shown in Figures 1 and 7. First we have the additional equipment consisting of the transformer, rectifier, and smoothing reactor. But also, the shunt motor has different characteristics from the series motors shown in Figures 1 and 6. The characteristics of the motor, shown in Figure 7, are similar to those of a direct current shunt motor. The speed, for any given setting, will be approximately constant, regardless of load. We can control the speed by field control, as we do with a direct current shunt motor, except that, instead of changing the field resistance, we will change the setting of the grids of the rectifier tubes for the field current; this will modify the effective voltage imposed on the field, and hence its current. We can also control the speed of this motor in exactly the same way we do the motor shown in Figure 1. Here we have a difference between this motor and a direct current shunt motor. We can control,

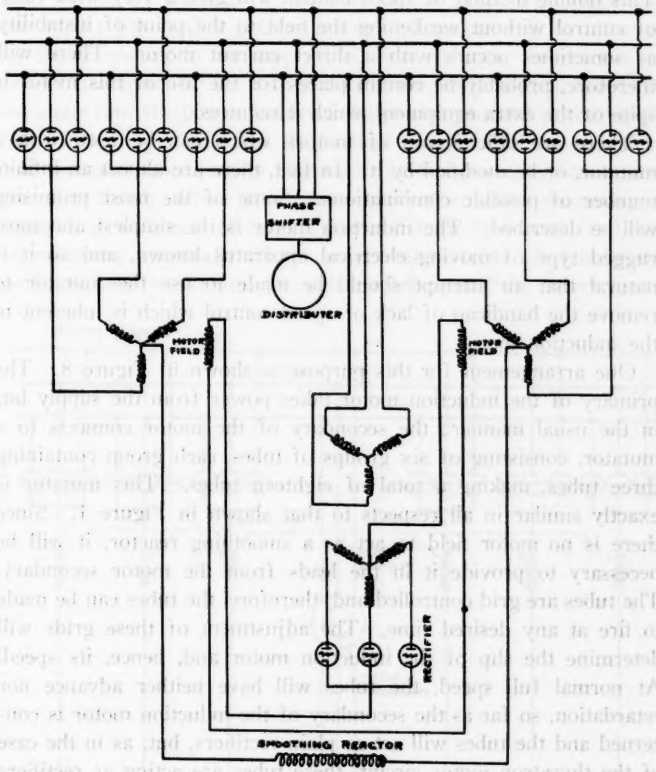
PHASE SHIFTER
DISTRIBUTER
MOTOR FIELD
MOTOR FIELD
RECTIFIER
SMOOTHING REACTOR

FIGURE 7.

not only by the field, but by the main current supply as well. The reason is, that we are controlling the supplied voltage, by changing the power factor, instead of by using a resistance (with its prohibitive loss) as we would have to do with a direct current motor. This double method of speed control will give a very wide range of control without weakening the field to the point of instability, as sometimes occurs with a direct current motor. There will, therefore, probably be certain places for the use of this motor in spite of the extra equipment which it requires.

There are other types of motors which can be used with a mutator, or be modified by it. In fact, there are almost an infinite number of possible combinations. Some of the most promising will be described. The induction motor is the simplest and most rugged type of moving electrical apparatus known, and so it is natural that an attempt should be made to use the mutator to remove the handicap of lack of speed control which is inherent in the induction motor.

One arrangement for this purpose is shown in Figure 8. The primary of the induction motor takes power from the supply bus in the usual manner; the secondary of the motor connects to a mutator, consisting of six groups of tubes, each group containing three tubes, making a total of eighteen tubes. This mutator is exactly similar in all respects to that shown in Figure 1. Since there is no motor field to act as a smoothing reactor, it will be necessary to provide it in the leads from the motor secondary. The tubes are grid controlled and, therefore, the tubes can be made to fire at any desired time. The adjustment of these grids will determine the slip of the induction motor and, hence, its speed. At normal full speed, the tubes will have neither advance nor retardation, so far as the secondary of the induction motor is concerned and the tubes will act as plain rectifiers, but, as in the case of the thyratron motor circuit, these tubes are acting as rectifiers with respect to one side of the circuit and as inverters with respect to the other side (in this case, the supply bus). And this will mean that, when, with respect to the motor secondary, the grid is neither advanced nor retarded, with respect to the supply bus the grid will be advanced and, hence the power factor, of the current returned to the supply bus, will be very low. Since this poor

power factor occurs at the normal full speed of the motor, it is particularly undesirable; the method of overcoming this defect will be discussed later. We will first discuss the method of obtaining speed changes. If it is desired to reduce the speed of the motor, then we reduce the angle of advance of the grids, with respect to the supply bus, and a greater amount of power will be returned by the secondary to the supply bus, thus reducing the amount of power consumed by the motor and hence, reducing its speed; at the same time the power factor of the power returned to the supply bus will be improved; also, the voltage generated in the secondary will increase, since its slip is greater; if this process is continued, we shall finally arrive at a point where the motor secondary is generating an e.m.f. of large value and high frequency, and will be returning practically all the power taken from the bus by the primary, back to the bus, through the tubes, and the power factor

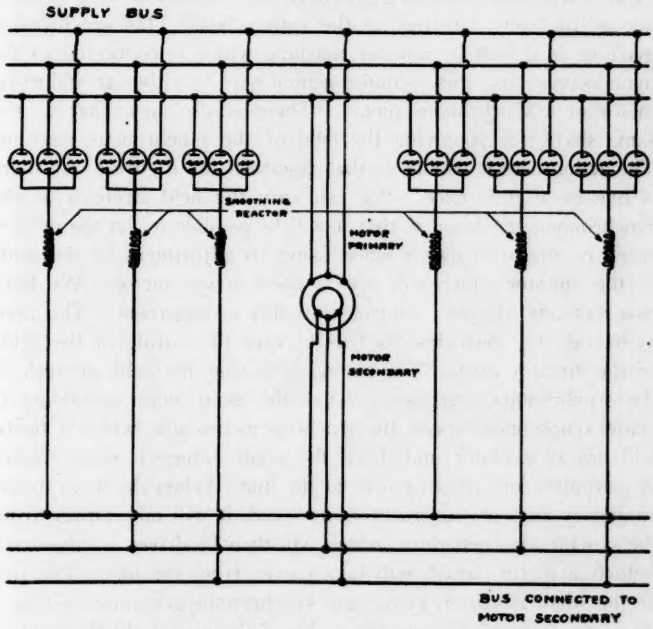

FIGURE 8.

will be very good under this condition; unfortunately, this condition only occurs at the low speeds. Now we may consider the higher speeds of the motor. If we wish to run the motor above synchronous speed, then we must reverse the setting of the grid, and the functions of the tubes will now be reversed; the tubes will become rectifiers with respect to the supply bus and inverters with respect to the motor secondary; this means that we are now supplying power to the motor secondary, instead of taking power from it. As before, the power factor will be poor for speeds near synchronism, but will improve as we go to higher speeds.

We will now consider a method for improving the power factor of this motor. In Figure 9, there is shown another arrangement for controlling the speed of an induction motor. Here we have the same arrangement as that shown in Figure 8, except that the output of the motor secondary is passed to a synchronous machine (which acts sometimes as a generator and sometimes as a motor), instead of being returned to the supply bus. This synchronous machine is driven by another machine which is connected to the main supply bus; this second machine may be either an induction motor or a synchronous motor. There is also an exciter on the same shaft, for supplying the field of the synchronous machine. The action here is similar to that described for Figure 8, but there is one great difference. We can vary the field strength of the synchronous generator so that it will be possible to get the desired speed of the main motor when using an adjustment of the grids of the mutator which will give a good power factor. We have two methods of speed control with this arrangement. The first, as has already been described, is to vary the setting of the grids of the mutator tubes. The second is to vary the field strength of the synchronous generator. When the main motor secondary is below synchronous speed, the synchronous machine, which it feeds, will act as a motor and drive the small induction motor above synchronism and return power to the line. When the main motor secondary runs above synchronous speed, it will take power from the synchronous generator, which will then be driven by the small induction motor, which will take power from the line. The size of the small induction motor and synchronous generator will be a direct function of the maximum slip of the main induction motor.

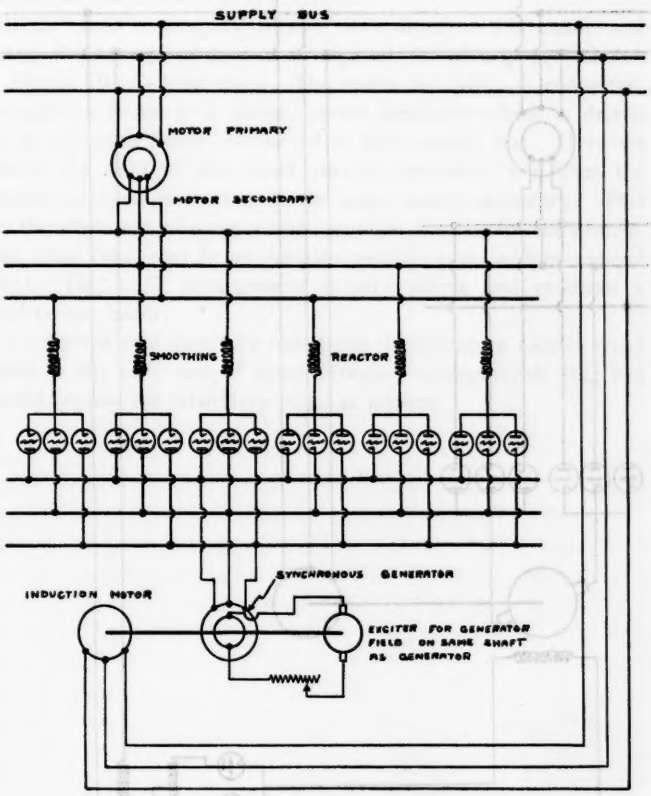
SUPPLY BUS
MOTOR PRIMARY
MOTOR SECONDARY
SMOOTHING
REACTOR
SYNCHRONOUS GENERATOR
INDUCTION MOTOR
EXCITER FOR GENERATOR FIELD ON SAME SHAFT AS GENERATOR

FIGURE 9.

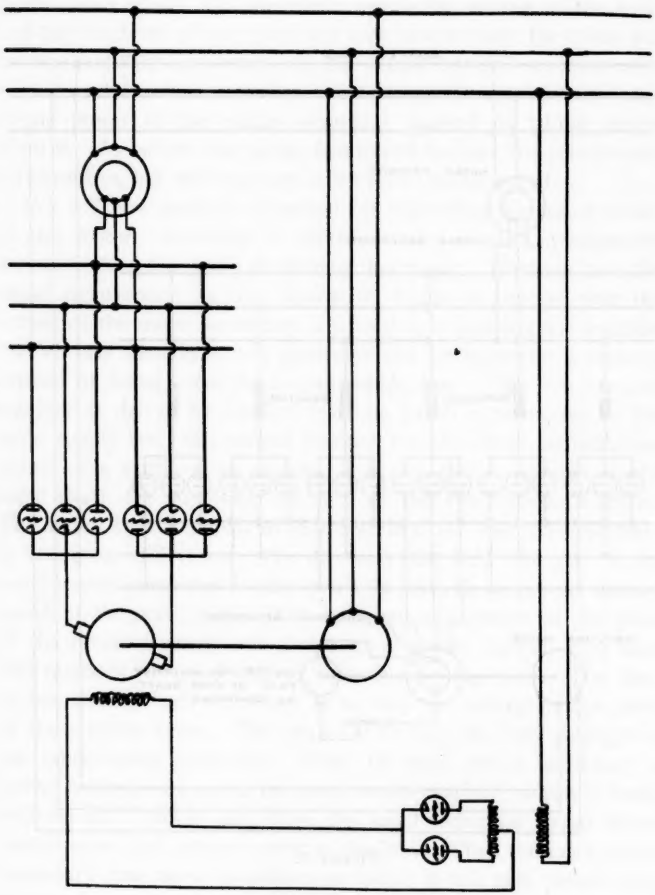

FIGURE 10.

However, if the torque requirements of the main motor fall off with speed, as would be the case with fans and similar loads, then the size of these units would be very small, even though they would be carrying a load which would be a large percentage of the load of the main motor, at low speeds.

In an effort to simplify further the control of this motor, and reduce the amount of apparatus required, the arrangement shown in Figure 10 has been tried. The motor secondary is connected, through six tubes, to a direct current generator which is driven by an induction motor, connected to main supply bus. Here we control the field of the direct current generator, and thus the amount of current flowing in the main motor secondary. This has the advantage of using a small number of tubes for the control. Also these tubes may be of the plain rectifier type, without control grids. The whole arrangement is very simple and produces a good power factor.

In conclusion, it should be stated that the thyratron (series type) motor is the only one of these proposed arrangements that has passed beyond the laboratory stage at present.

THE MODEL BASIN HIGH SPEED CAMERA FOR PROPELLER RESEARCH.

By Commander E. L. Gayhart (CC), U. S. Navy.*

In this article the author describes a new mechanical oddity developed by the U. S. Naval Model Basin personnel to meet the need for extreme rapidity in photography involved when pictures of a propeller travelling at full speed had to be taken. With the propeller turning in a tank, and only visible through a heavy glass viewing window, the unsatisfactory conditions may well be imagined. The urgent necessity for the elimination of all vibration in the focal unit, and the poor visibility made the problem an extremely difficult one to solve, and its solution reflects great credit on the ingenuity of the Laboratory personnel.

As an introduction to the following description of the high speed camera for propeller research at the Experimental Model Basin, it is desirable to begin with an outline of the conditions under which the camera is used and of the equipment which the camera supplements. The variable pressure water tunnel has already been fully described in the technical literature (Transactions of the Society of Naval Architects and Marine Engineers, Volume 38). At the risk of repetition, the reader will be informed that the testing chamber of the propeller tunnel is provided at each side with a glass port some 16¾ inches in diameter. Obviously, the only important visible manifestations on propellers and other objects in the stream of water are the various aspects of cavitation phenomena. The water, kept clear by filtering, enables easy visual observation, although the chamber is 27 inches net width, with the consequence that visual observations must be made through a thickness of 1 inch of glass and 13½ inches of water. The observation of such phenomena on rotating propellers is most conveniently made by

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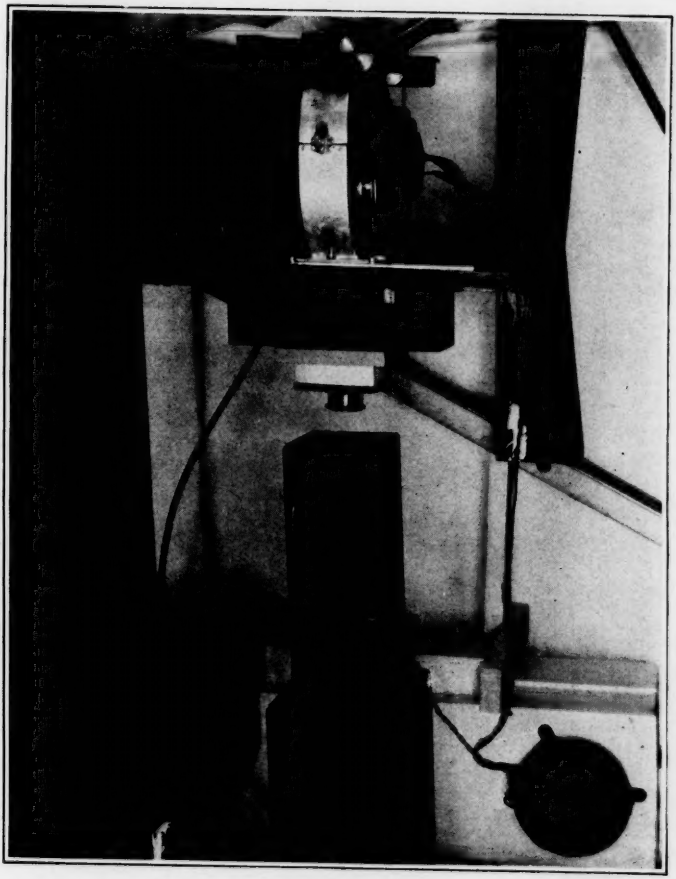


FIGURE 1.

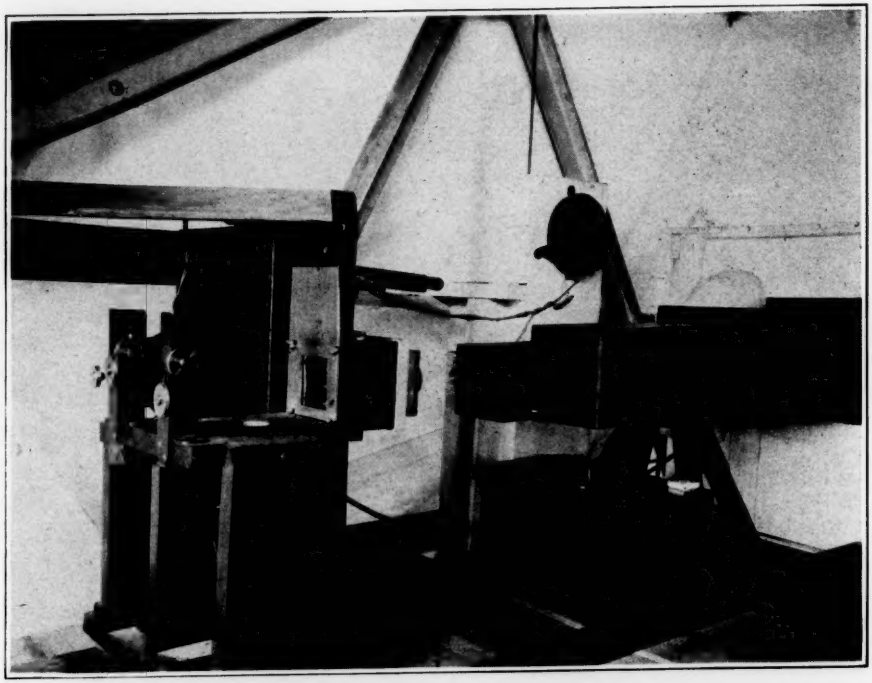


FIGURE 2.

use of some form of stroboscope. At the Model Basin, three types of stroboscopes have been used, first, a portable type consisting of a spring motor device for rotating a shutter at an adjustable speed, second, an interrupted light beam for illuminating the propeller with a flickering light timed to coincide with the frequency of the propeller blades, and third, a high intensity mercury arc whose flashing control is driven by a rotating contact on the propeller shaft. The first type of stroboscope referred to is commercially available under the trade name of "Rotoscope." This instrument, which is readily portable, has also been used for the observation of cavitation phenomena on the propellers of vessels at sea.

In the study of the details of cavitation, there are certain disadvantages in the devices of the stroboscope type. In the first place, the apparent illumination is very feeble. This is obviously due to the fact that the impression of intensity of light from the moving object is reduced in the ratio represented by the fraction whose numerator is the length of time during which the shutter is open or illuminant giving off light and whose denominator is the total length of the cycle. Referring to another principle of the stroboscope, the sharpness of definition obtained with the stroboscope is determined by the amount of motion during the illuminated portion of the cycle. The operator must, therefore, make a compromise between apparent illumination and definition. The hand-operated stroboscope gives good definition but the apparent illumination is very feeble. The stroboscope of the interrupted light beam type, which was developed for the water tunnel, gave fairly good illumination but the definition was not satisfactory. The high intensity mercury arc (the one in use at the Model Basin is the Edgerton Stroboscope manufactured by the General Radio Company) has a flashing time or duration of flash of the order of 5 micro seconds. The light intensity of the flash is very high, but because of the extremely brief flashing time, the impression on the eye is slight. Although this type of stroboscope gives definition of amazing sharpness, the apparent illumination is feeble and it was necessary to enclose the observation port with a small dark room before this stroboscope could give satisfactory observations.

Another difficulty which occurs with the stroboscope arises from the fact that these devices require a synchronization of the light

FIGURE 2.

flashes or observing shutter with the motion of the object being observed. In the hand-operated Rotoscope, there is a centrifugal governor which must be adjusted until the object observed apparently becomes stationary. In the stroboscope employing the interrupted light beam, it was necessary to adjust the speed of the motor which revolved the occulting shutter. The mercury arc stroboscope is self-synchronizing, that is, the contactor for controlling the flash is driven by the propeller shaft, an arrangement which automatically accomplishes synchronization and produces a perfect standing image. This contact arrangement (the actual contact is itself an automobile timer in which the multiple-faced cam has been replaced by a cam with a single face) offers the further advantage that the phase angle may be adjusted, analogously to the adjustment of the angle of spark advance in the automobile, and gives the impression of a movement of the propeller to any desired position within an angle of some 120 degrees.

All three types of stroboscope described above possess a common fault, namely, that the impression produced upon the eye is actually a composite resulting from the retention and overlapping of the impression on the retina of the rapid sequence of individual images.

The last mentioned objection to the stroboscope made it desirable to develop a camera which could take and preserve individual exposures. Otherwise, it would have been perfectly practicable to make time exposures of a standing image of a propeller apparently stopped by the application of the stroboscopic principle. In fact, experiments were made following this procedure and using the mercury arc stroboscope. In such a picture the propeller would be well defined because the picture consisted of a rapid succession of exposures on the sensitive plate of the repeated image of the propeller, but necessarily the cavitation phenomena would vary from one exposure to the next and the resulting picture would then show only the envelope and region of the cavitation phenomena in lieu of the details.

When it was decided to construct a camera that could take individual exposures in lieu of composite pictures, the following single consideration fixed its design, namely, that the time of exposure of the single image must be so brief that the tip of the propeller blade

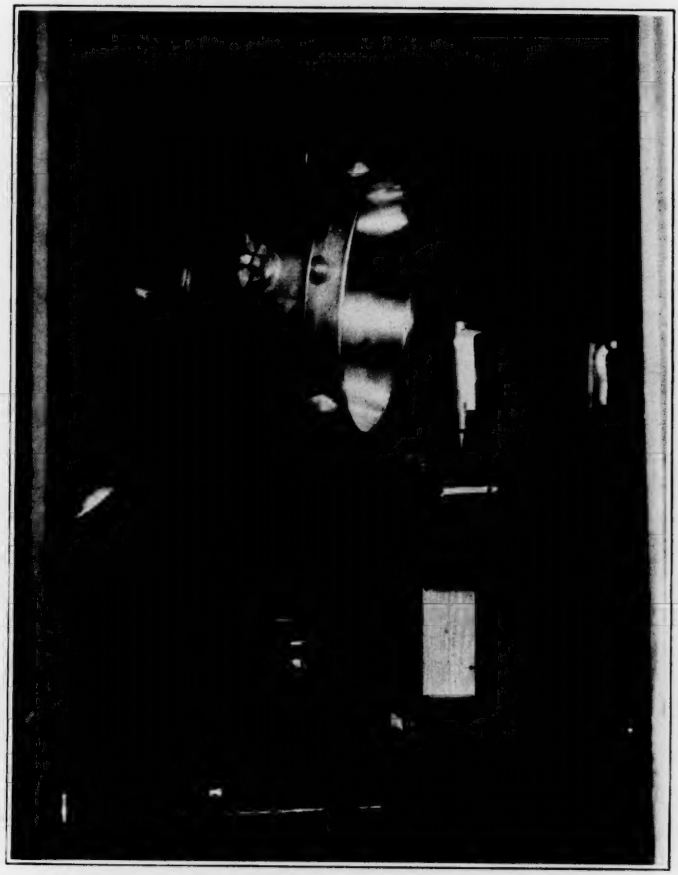


FIGURE 3.

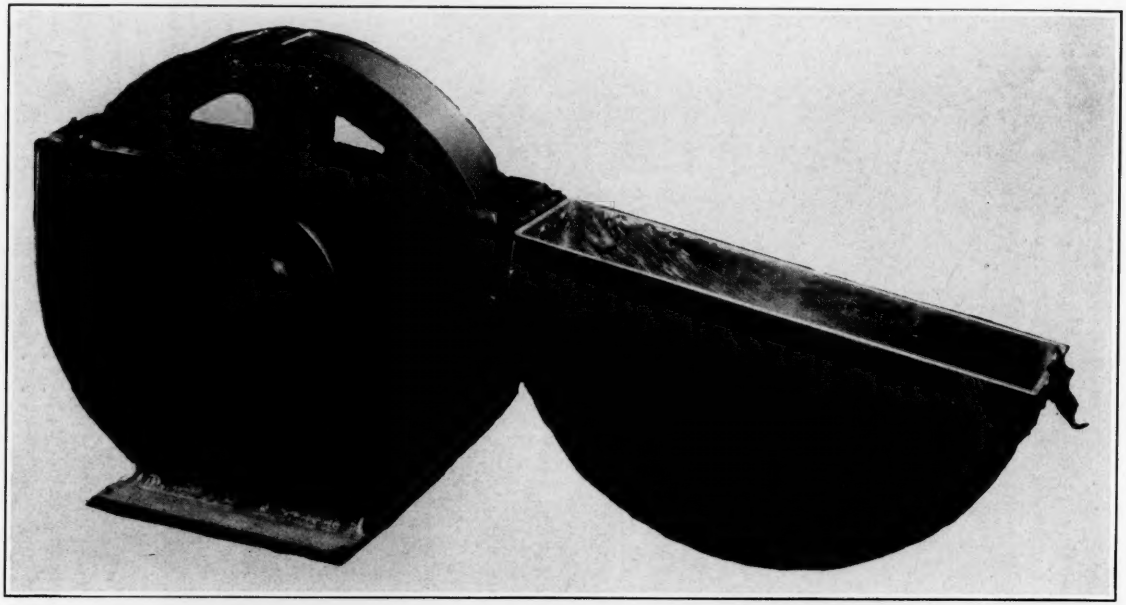


FIGURE 4.

will not move more than 1/100 of an inch during the exposure. The speed of rotation for model propellers when cavitating is of the order of 1400 R.P.M. for models of destroyers, which would correspond to a speed of rotation of the ship's propeller of approximately 350 R.P.M. (The law of comparison requires for propellers that the ratio of model speed to full scale speed vary inversely as the square root of the linear ratio.) An average propeller diameter is 8 inches. These considerations, namely, 1400 R.P.M., 8 inches diameter and peripheral motion limited to 1/100 inch, lead to an exposure time of approximately 1/50,000 of a second.

Two methods of arriving at a short exposure time are offered; one of them would be by spark photography and the other by a mechanical shutter. The plan for using spark photography was never seriously considered. To obtain the required amount of illumination from a spark would involve an inordinate amount of power with the attendant objections associated with the high voltage and noise and a probable difficulty of recharging the condenser and repeating the spark at a sufficiently rapid rate. In this connection, it is to be noted that the mercury arc stroboscope has a limit of 250 flashes per second.

FIGURE 4.

It was decided to use a mechanical shutter which, in view of the short exposure required, would be of necessity of the focal plane type. Mechanical considerations, such as the refinement required in the finish of the slit edge when using a very narrow slit as well as objectionable diffraction phenomena that would develop with the use of too narrow a slit, appeared to fix the desirable width at not less than 1/20 of an inch. The slit width of 1/20 of an inch and exposure time of 1/50,000 of a second would require a linear speed in a shutter curtain of 2500 inches per second. It would be impracticable to start and stop a shutter curtain and attain such a high curtain speed in any arrangement of the customary type. The high curtain speed could only be reached with a continuously moving curtain, which consideration leads to the obvious use of a radial slit in a revolving disc.

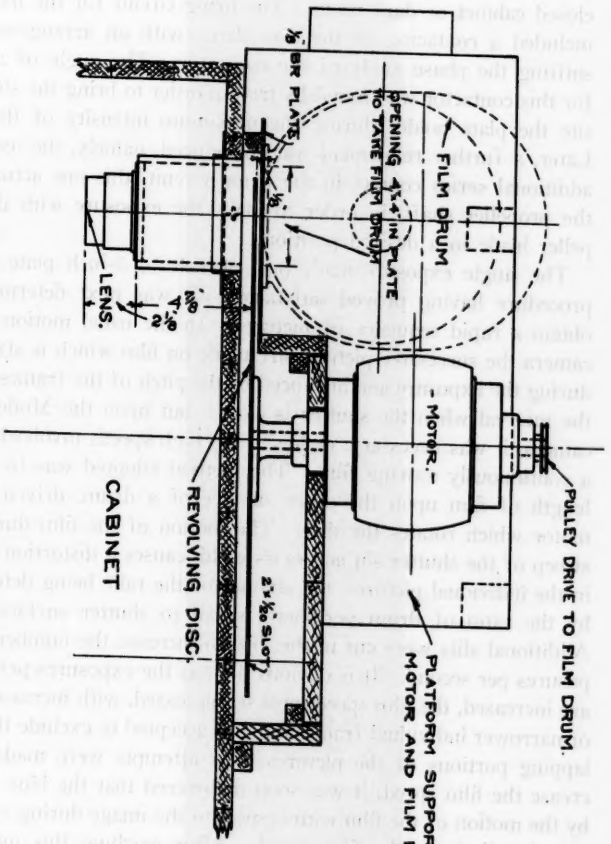
The shutter was therefore designed as a disc having an outside diameter of 20 inches and a slit 2 inches long with its outer end at a radius of 19½ inches. This disc, to attain the linear velocity of

2500 inches per second at the mean radius of the slit, must be driven at a speed approaching 40 revolutions per second which is the convenient value of 2400 R.P.M. In the use of the camera the disc is brought to and held at this speed by a stroboscopic control, timing the stroboscope with a 60-cycle A.C. impulse. At 2400 R.P.M., three radial marks on the end of the motor shaft appear stationary when illuminated at 60 flashes per second.

The problem of illumination offered some complications. The light must enter with oblique incidence upon the glass of the port, entailing perhaps a loss of 40 per cent. Furthermore, the light in its entire travel to the propeller and back to lens must traverse 27 inches of water and 2 inches of glass. This illumination problem was solved by the use of photo flash lamps. These lamps develop an extremely high intensity of light for a brief interval of time. The No. 75 photo flash bulb, which is used with this camera, develops a maximum intensity of 9,000,000 lumens and the intensity is in excess of 4,000,000 lumens for approximately 1/50 of a second. In other words, the peak candle power of such a flash lamp is well in excess of 750,000.

Originally, the flash bulbs were placed close to the glass port, suitably screened from the view of the camera. The illumination so obtained was not sufficiently intense and accordingly a reflector was developed for the purpose of concentrating the light upon the propeller. This reflector, which follows principles of geometrical optics, is shaped as an ellipsoid of revolution placed with the center of the lamp bulb at one focus of the ellipse and the propeller hub at the other. The arrangement of the reflector, which was built in the shop of the Model Basin, can be seen in the accompanying photograph, Figure 3, in which there is also to be seen the mercury arc stroboscope in the position where it is used for observing propellers.

The camera was originally constructed upon the wall of the small dark room (Figure 5) and worked out for making single exposures; a plate holder for 4-inch × 5-inch cut film was affixed to a light tight enclosure immediately back of the plane of the disc, with the radial slit sweeping across the narrow width of the film. The axis of the camera was placed to intercept the horizontal radius through the disc. The tangential motion of the slit was therefore vertical and in the plane of the propeller.



LAYOUT SKETCH OF HIGH SPEED CAMERA
PLAN VIEW

FIGURE 5.

The procedure for making the exposure consisted in bringing the motor disc up to speed, checking the same with the stroboscope, pulling the slide on the plate holder and firing the flash bulb in the closed cabinet or dark room. The firing circuit for the flash bulb included a contactor on the disc shaft, with an arrangement for shifting the phase angle of the contactor. The angle of advance for this contactor was found by trial in order to bring the slit opposite the plate holder during the maximum intensity of the flash. Later, a further refinement was introduced, namely, the use of an additional series contact in the firing circuit, this one actuated by the propeller shaft, in order to make the exposure with the propeller blade in a desired position.

The single exposure made on a 4-inch $\times$ 5-inch plate by this procedure having proved satisfactory, it was next determined to obtain a rapid sequence of pictures. In the usual motion picture camera the successive pictures are made on film which is stationary during the exposure and advanced by the pitch of the frames during the interval when the shutter is closed, but upon the Model Basin camera, it was necessary, owing to the high speeds involved, to use a continuously moving film. The method adopted was to wrap a length of film upon the outer surface of a drum, driven by the motor which rotates the disc. The motion of the film during the sweep of the shutter slit across its width causes a distortion or rake in the individual pictures, the amount of the rake being determined by the ratio of drum peripheral speed to shutter surface speed. Additional slits were cut in the disc to increase the number of exposures per second. It is obvious that, as the exposures per second are increased, the film speed must be increased, with increased rake, or narrower individual frames must be accepted to exclude the overlapping portions of the pictures. As attempts were made to increase the film speed, it was soon discovered that the blur induced by the motion of the film with respect to the image during exposure placed a limit on the film speed. After reaching this maximum permissible film speed as limited by blur, an increase in the exposures per second could only be obtained by accepting a narrower frame for the single pictures. The final compromise in the design was reached by the use of 24 slits in the disc, which with the velocity of 40 revolutions per second produced an exposure rate of 960

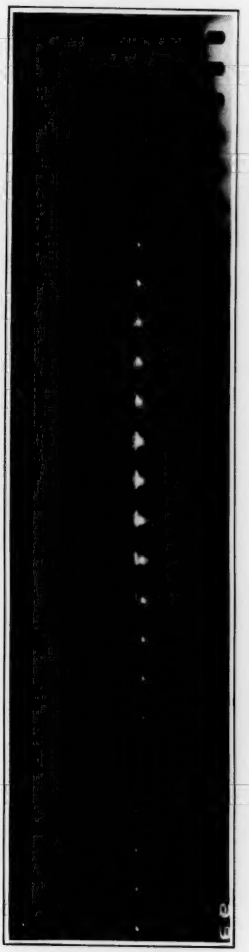


FIGURE 6.

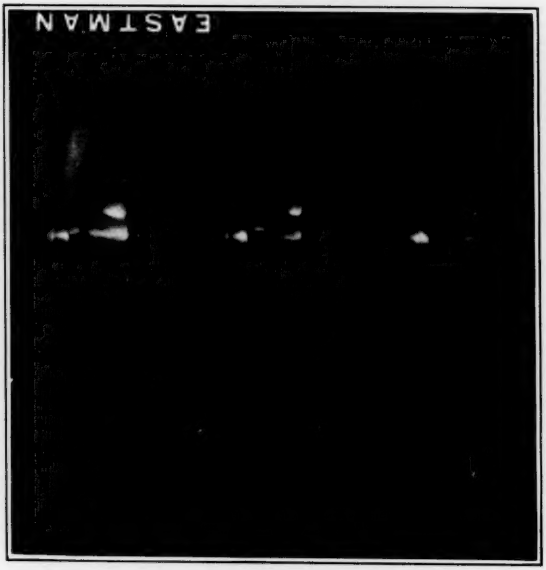


FIGURE 7.

frames per second. Pulley sizes were then worked out for the motor and film drum which give a pitch of the individual frames on the film of approximately ¼ inch, which is a sufficient width to accommodate the image of the hub of any propeller ordinarily to be met with. The film drum, which is 10 inches in diameter, uses a strip of standard 35 millimeter motion picture film somewhat over 30 inches long.

As mentioned before, the camera was originally constructed upon the rear wall of the light-tight cabinet which encloses one of the propeller observation ports. Later the camera was reconstructed and placed upon wooden rails which would permit it to be moved to various distances from the propellers, and allow the use of lenses of various focal lengths. A wooden duct in telescoping sections was made to connect the lens board of the camera to the opening in the side of the dark room. The resulting arrangement of the camera is shown in Figures 1 and 2. In Figure 2, the film drum is removed, exposing to view a portion of the disc, with several slits clearly evident.

Some examples of the photographs produced by this camera appear in Figures 6, 7 and 8. The useful portion of the flash is generally of sufficient duration to produce exposures on 16 or 17 frames, of which 8 or 10 will be fully exposed. Figure 6 is a strip of pictures in natural size, 960 exposures per second. In this view, the film is traveling from right to left and illustrates the rapid growth of light intensity and the slow dying out of the light with the central useful portion extending over about 8 frames. Figure 7 is an enlargement of a strip of film with the width of the frames increased in order better to show the peculiar pattern made by the propeller tip vortices. In this view, where the cavitation on the back of the blade is clearly evident, the growth and motion of the bubbles can be followed by examining successive frames. The interval between frames is 1/480 second in this Figure. In Figure 8, showing cavitation on another propeller, numerous bubbles also can be seen in the current beyond the propeller.

This camera was developed early in 1935. The first single exposure photographs on 4-inch × 5-inch cut film were made on or before May 1 of that year. The moving film drum was developed and installed and photographs were made by this arrangement on

or before July 24, 1935. Since that date the camera has been used as a matter of routine in propeller study.

Use of the camera has brought out the desirability of change in certain respects with the object of improvement in illumination and in definition. In particular, the camera as originally designed could not utilize effectively the full aperture of the photographic objective. With the disc at a distance of nearly ⅜ inch from the film, the angle subtended by the slit width of 1/20 inch corresponded in the language of photographers to an aperture of F/8, while the lens has an aperture of F/4.5. In other words, a point on the surface of the film can not receive light at one time from more of the lens than about half its diameter (in the direction at right angles to the slit). The slit acts as a rectangular diaphragm stop on the lens undoubtedly causing an unusual distribution of the effect of the errors of the lens.

Furthermore, the separation of the disc from the focal plane reduces the efficiency or light transmitting capacity of the shutter. This efficiency is the ratio of the total light action upon an element of film surface during an exposure as compared with the action that would result if the light were of full intensity for the entire exposure. In other words, shutter efficiency recognizes the fact that part of the exposure time is used in opening and closing the shutter with full intensity transmitted only during the middle portion.

The camera was redesigned to improve the aperture and shutter efficiency. This was accomplished in part by a new film drum and container, in which the film surface is brought closer to the disc than previously. The reduced separation simultaneously increases the aperture as well as the efficiency. The improved drum, which has been completed, is already in use on the present camera, and is illustrated as Figure 4.

In the new camera design, the effective aperture of the shutter will be further increased by using a slit width of 1/10 inch, which, with the drum change, brings the aperture to F/2.5. After doubling the slit width in the new design, it becomes necessary to double the peripheral speed, which is accomplished by the construction of a new disc of approximately double the former diameter. This larger disc gives the same exposure time as previously without increasing

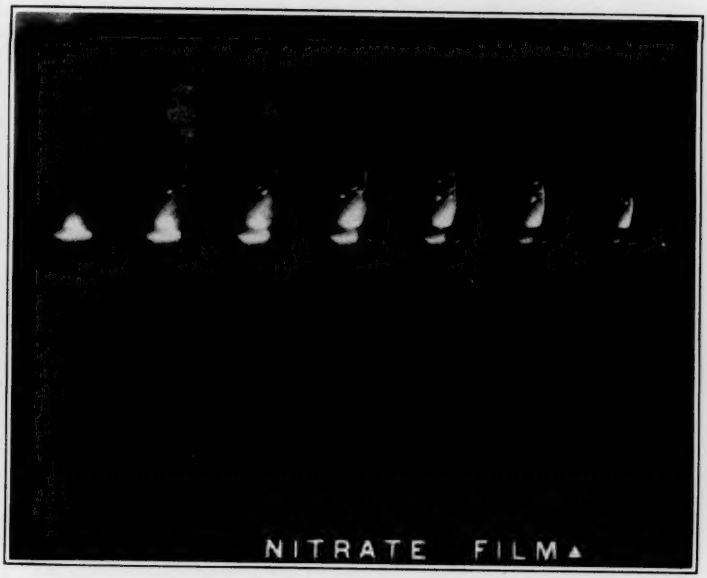


FIGURE 8.

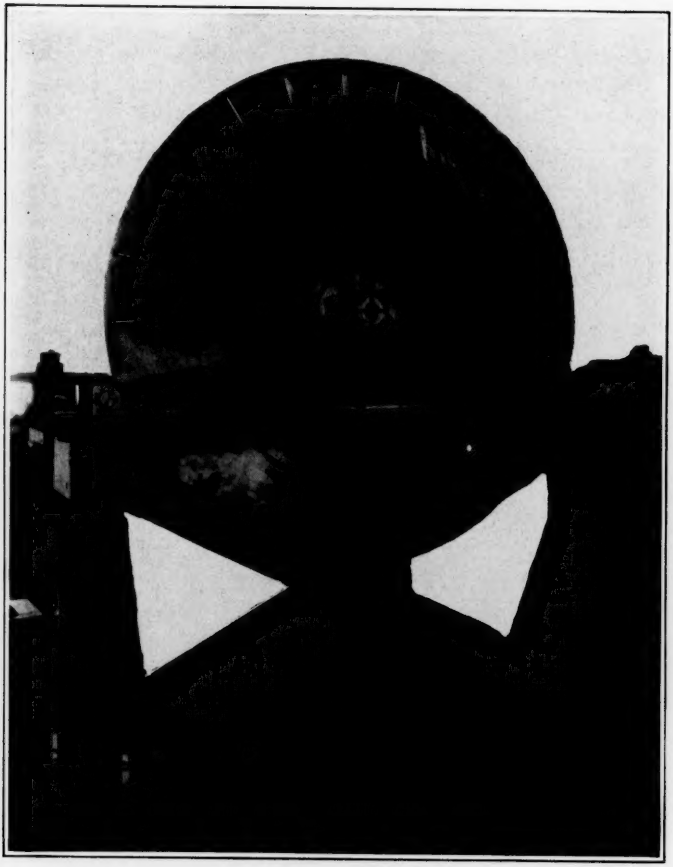


FIGURE 9.

the angular speed. The shop assembly of the new disc with shafting and bearings appears in Figure 9.

With the object of improving definition, in so far as the pictures taken with the present camera may suffer from the effect of vibration, the new design includes two distinct improvements. In the first place, the relatively heavy disc will be surrounded by a steel cylindrical ring ⅜ inch thick and several inches wide to serve as an enclosing guard. The inertia of these two members is expected to shut off any vibrations of high frequency in the structure as a whole. As a further measure against the effect of vibration, the lens support will be carried as a rigid U-shaped yoke around the edge of the disc. This yoke will hold the lens in a fixed position with respect to the film drum, will reduce the motion of the image with respect to the film, and eliminate such lack of definition as arises from that cause.

PROPRIETARY PURCHASE.

By Lieutenant Commander Guy Chadwick, U. S. Navy, Member.*

This article can be read with profit by any officer having to do with the purchase of Government materials, and it should be informative to vendors of such materials who are mystified by the legal processes which surround a Government contract. The study which has been made by the author seems to indicate that some further amplification of the basic law by Congress would be of definite benefit to the Federal activities which must purchase under its provisions. The statute has been on the books now for some seventy-five years, and through these years volumes have been written by Attorneys General of the United States, and by the Comptroller General, in interpreting its meaning in varying applications. Its requirements have been modified by subsequent acts in a few specific cases to meet a particular need, but it has never been generally revised to bring it more into accord with experience.

"All purchases and contracts for supplies or services, in any of the Departments of the Government, except for personal services, shall be made by advertising a sufficient time previously for proposals respecting the same, when the public exigencies do not require the immediate delivery of the articles, or performance of the service. When immediate delivery or performance is required by the public exigency, the articles or service required may be procured by open purchase or contract, at the places and in the manner in which such articles are usually bought and sold, or such services engaged, between individuals."

Section 3709 of the Revised Statutes, quoted above, is the basic law under which supplies and services are procured by the Government. This law has been in effect since the year 1861. Although

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later statutes and acts have modified it in respect to certain specific applications, no changes have been made that affect its general nature.

The vast Government purchases made under this statute have occasioned many decisions and explanations as to its interpretation. Voluminous sources are found in Comptroller General decisions and court decisions, as well as in circular letters, regulations and manuals issued by administrative offices.

Now, it is readily apparent that no person involved in the design, use, supply, or procurement of materials for the naval establishment can remain unaffected by the legal conditions of purchase. It is equally apparent that many such persons, should they attempt to wade through the ramifications of the available literature, would have little time left over to design, use, supply, or procure. Therefore, it is proposed to derive and present in this article such suggestions as may be of value to promote a simplified understanding of the procurement problem.

TWO METHODS OF PURCHASE.

A brief examination of the basic law will reveal two distinct methods by which government purchases may be made. The first method is indicated in the words: ". . . by advertising a sufficient time previously for proposals . . ." The second method is: ". . . by open purchase . . ."

At first glance it might appear that a choice of methods of purchase would simplify the problem. This is not the case. The law does not permit a free choice as to the method used. On the contrary, restrictions are set up under which the choice of a particular method becomes mandatory. In addition, conditions frequently arise to obscure the distinction between the two methods. All this places an additional burden of responsibility on the purchasing agency.

PURCHASE BY ADVERTISEMENT.

". . . by it the Government is given the benefit of the competition of the market and the bidder is given the chance for a bargain . . ." (U. S. v. Purcell Envelope Co., 249 U. S. 313, 318.)

". . .: In the case of provisions, clothing, hemp and other materials, the Secretary of the Navy shall advertise, twice a week for

two weeks or longer, not to exceed four weeks, or once a week for two weeks or longer, not to exceed four weeks, . . ." Sec. 3718 Revised Statutes.

To advertise is to make known by public notice. Ordinarily, when we speak of *advertisement,* we have in mind the great modern system by means of which vendors give publicity to their wares. But the use of advertising need not be restricted to the vendor. The buyer may employ advertising to make public his needs. It is this latter application which is contemplated by the statute.

Now, the vendor, in advertising, is successful in proportion to the number of buyers whose attention he attracts. In the same way, purchase by advertisement is fully successful only when all sources of supply are reached. This is the first condition to be complied with.

Having advertised our needs we must complete the process of purchase. In the auction room the auctioneer sells his wares to the buyer who makes the best bid. Purchase by advertisement contemplates that the vendor do the bidding. Award is then made according to the most favorable bid. This is the second condition to be complied with.

One more point must be considered. It is the time element. Allowance must be made for the periods which are consumed by the buyer in advertising and by the vendor in making up and submitting his bids. This is the third condition to be complied with.

Purchase by Advertisement, then, may be defined as procurement by advertising a sufficient time in advance to permit all vendors to submit proposals for acceptance according to the best advantage of the purchaser.

PROPRIETARY PURCHASE.

Again referring to the basic statute, it will be noted that the alternative to purchase by advertisement is ". . . purchase . . . in the manner in which such articles are usually bought and sold, . . ., between individuals."

Here we are confused. There are many ways of buying and selling. These include barter, auction, cash, credit, and sucker. Obviously, we are off the track and must look for help.

A helpful directive may be found in the terms used in official publications to designate this type of purchase. Such designations

as *open purchase, local purchase,* and *sundry purchase* occur frequently. These terms infer a freedom on the part of the purchasing agency to predetermine just what article he will purchase. In other words, free competition among the vendors is restricted and the purchaser decides what he will buy before he writes the requisition.

Keeping this in mind, we will call the article thus purchased a proprietary article and identify it as one in which the manufacturer has a property right that by law or custom, may not be used by another. Such a property right may be protected by patent, copyright, or general acceptance among reputable business concerns. It may be recognized by an identification such as a brand name or a trade-mark.

Proprietary purchase, then, is the alternative method of purchase and may be defined as the procurement of a proprietary article without allowing free competition between all vendors subsequent to the time of requisition.

PURCHASE BY ADVERTISEMENT THE PREFERRED METHOD.

We have seen that there are two methods of purchase. Such being the case, we must decide which to use. This decision, of course, will be based on the circumstances surrounding the purchase in question. However, we have available a guiding principle to assist us in making our choice. This principle is that purchase by advertisement must be made in default of circumstances which dictate proprietary purchase. "Requisitions shall not call for proprietary articles in any case where it can be avoided, . . ." U. S. Navy Regulations, 1920.

The regulation is crystal clear. In its support we will find many laws which emphasize the preference for an unrestricted competitive market. The following are quoted:

"That no contract for the purchase of gun steel or armor for the Navy shall hereafter be made until . . . submitted to public competition . . . by advertisement." Act of March 3, 1893.

". . . all awards of contracts for provisions for the Navy shall be made by individual items; the contract for each item being awarded to the lowest responsible bidder." Act of March 4, 1913.

"Every person who shall monopolize . . . trade . . . shall be deemed guilty of a misdemeanor, . . ." Act of July 2, 1890.

"That it shall be unlawful for any person . . . to discriminate in price between different purchasers . . . where the effect of such discrimination may be to substantially lessen competition . . ." Act of October 15, 1914.

"No patented article connected with marine engines shall hereafter be purchased or used in connection with any steam vessels of war until the same shall have been submitted to a competent board of naval engineers, and recommended by such board, in writing, for purchase and use." Sec. 1537 Revised Statutes.

PURCHASE BY ADVERTISEMENT WHEN TIME PERMITS.

Keeping in mind that purchase by advertisement is the preferred method, we now cast about for another guiding principle that will show when to make a proprietary purchase.

"Where the public exigencies do not require the immediate delivery of the articles, or performance of the service, it is necessary to advertise previously for proposals respecting the same, but where immediate delivery is necessary the article must be obtained by open purchase." (1829) 2 Op. Atty. Gen. 257.

"The 'public exigency' contemplated by this section is one of time only." (1877) 15 Op. Atty Gen. 254.

"Purchases in open market cannot be resorted to, except in cases of, and in reference to, such articles as are wanted for use so immediate as not to permit of contracts by advertisement." (1846) 4 Op. Atty. Gen. 475.

"Immediate purchase under open-purchase requisitions shall be ordered only when an exigency exists that will not allow delay incident to advertisement and contract." U. S. Navy Regulations, 1920, Art. 1605(1).

The above four interpretations of the basic law are supported by many more from authoritative sources. These combine in emphasizing that proprietary purchase is permissible only when time to advertise is lacking. Later we will discuss specific exceptions to this rule, but nowhere will be found a general guiding principle at variance with it.

ADMINISTRATIVE PROCEDURE TO PROVIDE TIME FOR ADVERTISING.

"An officer in command of a military department may decide as to the existence of an 'exigency' which will excuse the omission to advertise . . . there being nothing in the case to show the exigency was not real . . . and the result of necessity." Stevens v. U. S. (1866) 2 Ct. Cl. 95.

But suppose there were something in the case to show that the exigency was not real. That would be embarrassing. Therefore, it becomes of urgent necessity to set up administrative methods that will permit time for advertisement and not, of themselves, create exigencies.

Fundamentally this means foresight on the part of those responsible for initiating requisitions. But procurement planning which contemplated an unlimited time available between requisition and award of contract would place too great reliance on the ability of the organization to foresee its own demands. Of necessity, systems have been developed to shorten the period of purchase by advertisement. The more important of these are listed as follows:

1. *Purchase by Specification*—The majority of items purchased are recurrent. In order to avoid redundancy in schedules submitted for bids, it has been found useful to prepare in advance suitable specifications detailing the particulars of the article desired. These specifications may be of a general nature covering, for example, the performance requirements of a machine; or they may be precise as to the material and workmanship of a given article. They become an integral part of schedules by reference therein.

2. *Requisitions and Schedules*—In order to speed up and simplify the preparation of these, forms, standard paragraphs, sequences, and phraseology are provided that, from experience, are most suitable.

3. *Mailing List of Regular Dealers and Manufacturers*—In addition to the general newspaper advertisement of schedules, lists of producers and vendors are maintained and classified. By referring to these lists, schedules may be transmitted direct to prospective bidders without the delay and uncertainty involved in newspaper advertising.

4. *Long Term Contracts*—Several classes of commodities as, for example, fuel oil, stationery, and certain provisions, are subject to

frequent repetition of delivery in small quantities. Under certain statutory and administrative restrictions, contract may be made for multiple deliveries of these commodities, thereby reducing the number of schedules to advertise. With few exceptions, such contracts are limited by statute to the duration of one year.

5. *The Navy Department Acceptable List of Approved Materials*—This list includes materials which require extended tests prior to acceptance for naval use. Its purpose is to facilitate the purchase of satisfactory materials in one or more of the following cases:—

(*a*) The time required for complete test is so great as to delay delivery.

(*b*) The cost of inspecting individual orders is prohibitive.

(*c*) The necessary tests require complicated and extensive apparatus not in general commercial use.

(*d*) The technical requirements cannot be fully described by a specification.

(*e*) The material is of an experimental nature for use until specifications are developed.

Dealers and manufacturers are afforded the opportunity to have their materials tested in advance for suitability. For a given material, several quick sources of supply thereby become immediately available.

It is particularly to be noted that this is a list of specific articles or brands and not of approved manufacturers. Constant supervision is required to provide unrestricted opportunity for manufacturers to list their products. On the other hand, the types of articles listed must not extend beyond the purposes of the list.

6. *Field Inspection System*—This system has its offices and branch offices throughout the United States. Its purpose is to provide naval inspectors to witness the suitability of articles in time for early delivery.

7. *Test Laboratories*—Not only government laboratories but certain approved private laboratories are made available for rapid determination of the suitability of articles.

ADVERTISING DOES NOT SECURE AGAINST PROPRIETARY PURCHASE.

Free competition may be prevented even though we adhere to the normal procedure of advertising. We have seen how to avoid the trap of false exigencies. But there remains another danger to be guarded against. This danger lies in restricting the conditions of purchase.

RESTRICTIVE SPECIFICATIONS.

". . . no arbitrary specifications . . . may be used for the purpose of excluding from competition . . ."

". . . the specifications instead of describing the job to be done merely specified by name a certain patented or proprietary product . . . the evident purpose being to prevent competition."

". . . the proposal for bids must be such as to invite competition between all dealers of whatever make in that or superior grades of equipment, . . ."

". . . under the existing law governing the purchase of equipment, supplies, materials, etc., for the Government the controlling element is the job to be done, the work necessary to be accomplished. The request for bids should fairly reflect the actual need through specifications or otherwise, . . ."

". . . appropriated moneys are avilable for purchase only of what is needed as distinguished from what may be desired."

" It has not been shown . . . that there are no . . . six-cylinder automobiles . . . sufficiently sturdy . . . to meet every service requirement . . . Hence, there would appear no authority for the requirement of an eight-cylinder car . . ."

". . . an unfortunate . . . tendency . . . to exaggerate the rigors of service requirements in an attempt to justify restrictive specifications."

The above quotations are from decisions by the Comptroller General of the United States. Their significance is too obvious to require explanation.

Nevertheless, it will be interesting to note some points which should be kept in mind to avoid writing restrictive specifications. The first, and probably the most important of these points is expressed in another decision by the Comptroller General as follows:

" Administration reports . . ., obviously should not be based on

advertising matter—the 'sales talk' of the manufacturer of the desired equipment, but upon an impartial finding of facts, sustained by evidence."

The specification writer is subjected to sales propaganda from all sides. He is flooded with circulars and trade publications of every description. In his endeavor to keep in touch with the available market, he must interview and correspond with representatives of commercial concerns. The point of view of these representatives is not always unbiased. The force of suggestion is strong. It must be resisted to the extent that reasoning be not overcome by persuasion.

Having successfully resisted sales talk he should avoid other pitfalls. He should not write a specification around a proprietary or patented article. He should not favor the equipment of a particular manufacturer. He should shun such facile methods as referring to catalogue cuts, even though these be termed "descriptive not restrictive." He should not include nonessential dimensions in descriptive drawings of interchangeable parts. He should avoid unnecessary standardization of equipment. He should be wary of copying specifications of trade associations which are controlled by producers.

Then, as a last precaution, he should write a specification that is simple, clear, and easily understandable. He should not inhibit competition by confusing the competitor. The latter's time may be too valuable to spend in deciphering abstruse requirements.

RESTRICTIVE DELIVERY.

In writing up schedules for bids, the place and time of delivery are designated. It is plain that time of shipment will vary according to the location of the manufacturer's plant or the vendor's storehouse. Consequently, care must be taken to provide a reasonable time for delivery in behalf of each bidder.

It is likewise apparent that one bidder may have a stock of the required material ready at hand, while another may have to assemble or even manufacture the material. This, also, must be taken into account in providing for delivery time.

Again, the facilities afforded for inspection may differ among bidders. Thus, it is seen that an inequitable allowance of delivery time may act to restrict free competition.

IRREGULARITY ON THE PART OF THE BIDDER.

"No contract or order . . . shall be transferred by the party to whom such contract or order is given to any other party . . ." Sec. 3737 Revised Statutes.

"One of the purposes of the section was to secure integrity in bidding for contracts, by preventing a bidder or contractor from making several bids, one by himself and others by his friends or employees, to be afterwards consummated by assignments . . . to the real bidder, for whom they all acted. Another was to prevent those who bid for and obtain contracts for mere speculation . . . from selling the contracts at a profit to bona fide bidders or contractors." (1888) 19 Op. Atty. Gen. 187.

We may perceive that this section of the statutes has a marked effect in maintaining fair and equitable competition to the advantage of both the government and the reputable bidder.

". . . In case of failure to supply the articles . . . by the person entering into such contract, he and his sureties shall be liable for the forfeiture specified in such contract, as liquidated damages, to be sued for in the name of the United States." Art. 3720, Revised Statutes.

It is of interest to note two ways in which the above law may be manipulated to the advantage of an unethical bidder. The first way occurs in connection with a large construction program as in the machinery installation of a ship. Here deliveries of the different parts must be nicely timed to fit in with the progress of construction. The delay of a single delivery may retard the entire construction program. Presently, an article is delivered in the nick of time. This article proves to be of inferior quality and cheaper construction than that called for in the specifications. But a costly delay would result from the time consumed in rejection and readvertisement. Consequently, it may become of immediate advantage to the government to withhold action against the contractor, even though acceptance of the inferior product may occasion expensive replacement at a later date.

The second manipulation occurs in connection with liquidated damages. To insure timely deliveries, the contract may penalize the supplier who is late. It is obvious that should too great a penalty be written into the schedule, bidders would hesitate to

accept the chance of penalty and free competition would be inhibited. On the other hand, a moderate penalty may be accepted by a bidder with a view to forfeiture at his own convenience. In some cases a manufacturer may find that lower cost of production will result from slowing up work on the product, the decrease in cost equalling or exceeding the amount of liquidated damages. He may conceive legal subterfuges to hold the Government responsible for delays which are rightfully his. Or he may discount the amount of liquidated damages by raising the amount of his bid. In either case, the Government suffers.

SPECIAL CASES OF PROPRIETARY PURCHASE.

We have seen that the basic law does not permit proprietary purchase when time is available for purchase by advertisement. However, there are certain exceptions to this rule. Upon occasion, the law has recognized special cases where proprietary purchase may be made even when time to advertise is available. In order to complete our inquiry into the legal aspects of proprietary purchase, the exceptional cases which apply particularly to the Navy are presented.

"The purchase of supplies and the procurement of services for all branches of the naval service may be made in open market in the manner common among business men, without formal contract or bond, when the aggregate of the amount required does not exceed $500, and when, in the opinion of the proper administrative officers, such limitation of amount is not designed to evade purchase under formal contract or bond, and equally or more advantageous terms can thereby be secured." Act March 2, 1907.

"The provisions which require that supplies shall be purchased by the Secretary of the Navy from the lowest bidder, after advertisement, shall not apply to ordnance, gunpowder, or medicines, or the supplies which it may be necessary to purchase out of the United States for vessels on foreign stations, or bunting delivered for the use of the Navy, or butter or cheese destined for the use of the Navy, or things contraband of war. . . ." Sec. 3721 Revised Statutes.

". . . the Secretary of the Navy . . . is hereby authorized to purchase at the lowest market price, such plate iron and other

material as may enter into the construction of steam boilers for the Navy, without advertising for bids to furnish the same: . . ." Provided that specifications be sent to the principal dealers and manufacturers and that regular inspections and tests are made. Act of June 14, 1878.

". . . this restriction shall not apply to purchases of shells or projectiles of an experimental nature or to be used for experimental purposes and paid for from the appropriation 'Experiments, Bureau of Ordnance': . . ." Act of June 30, 1914.

"The Secretary of the Navy is authorized to procure the preserved meats, pickles, butter, and desiccated vegetables, in such manner and under such restrictions and guarantees as in his opinion will best insure the good quality of said articles." Sec. 3726 Revised Statutes.

"The Secretary of the Navy is authorized to purchase, in such manner as he shall deem most advantageous to the Government, the flour required for naval use; . . ." Sec. 3727 Revised Statutes.

"The object of the section in requiring advertisement . . . is to invite competition among bidders, and it contemplates only those purchases and contracts where competition . . . is possible . . ." (1881) 17 Op. Atty. Gen. 84.

ADDITIONAL CASES WHERE PROPRIETARY PURCHASE COULD BE LEGALIZED TO ADVANTAGE.

The exceptional cases quoted above have one common factor. They are all specific in their application. Possibly they are too specific. If we may make a proprietary purchase of ordnance, why may we not purchase marine engines in a like manner? If we may buy experimental projectiles by proprietary purchase, why not experimental pistons for Diesel engines? These and similar questions lead us to search for a broader basis upon which to build our exceptions to the basic law.

The need for legal exceptions based upon general principles rather than upon specific applications becomes apparent when we review actual cases of procurement. The following two instances will serve to illustrate. Both show how the reasonable needs of the Government, as interpreted by administrative authority, conflict with the requirements of the law, as interpreted by the Comptroller General.

The first case has to do with the purchase of repair parts for mechanical equipment.

Argument by the Administrative Authority:

"The repair parts . . . consisted of . . . electrical parts for graders and household ranges, . . . parts for rock drills, electrical propelling equipment for tug boats, paving breakers, jack hammers and air compressors, . . . parts for automatic telephones, . . . parts for . . . motor vehicles. . . .

"These parts are proprietary to the manufacturers of the particular machinery and equipment and cannot be procured from dealers in general. They are not articles for the furnishing of which there could be any competition, and advertising under these circumstances would accomplish no useful purpose.

"It is the duty of our Purchasing Department to procure supplies at a minimum cost with a maximum service, having in mind the best interests of the United States Government. Experience over a period of years has demonstrated the futility of repeatedly advertising for parts for specialized equipment . . . The parts are made from patterns and specifications peculiarly characteristic to the equipment to which they pertain; they are proprietary to the manufacturer of the equipment, and the manufacturer is the sole distributor. Parts for equipment manufactured by one concern are not interchangeable on equipment manufactured by others, and manufacturers do not produce parts for equipment made by competitors. Furthermore, it would be impossible for a procuring agency to prepare minute specifications for the thousands of parts characteristic to specialized machinery and equipments.

"Until relatively recent years the needs for '(automobile)' parts were advertised for under circular invitations and bids were received repeatedly from only the manufacturer. After following this procedure for a considerable period of time, it was determined that advertising would serve no useful purpose and advertisement for these parts was also discontinued with the resultant savings of considerable expense in the preparation of invitations for bids and work relating thereto."

Decision by the Comptroller General:

". . . it cannot be assumed, in the absence of advertising, that no one except the manufacturer of the particular equipment may

submit a bid for furnishing spare parts. Spare parts to equipment are not infrequently carried in stock by dealers, jobbers and others, and in some instances, spare parts are manufactured by others than the manufacturers of the equipment. Section 3709, Revised Statutes, does not permit of any discretion in this matter, and if it be of belief '(of the purchasing agency)' that it should have authority to purchase spare parts without advertising, the matter would appear to be for presenting to the Congress with a view to obtaining legislation similar to that obtained by the Post Office Department in the act of June 30, 1930, 46 Stat. 838, as follows:

"'That whenever motor-truck parts are needed by the Post Office Department in the operation of motor trucks, the Postmaster General is hereby authorized to enter into agreements with truck manufacturers for the purchase of such truck parts at a price not exceeding the truck manufacturer's list price less regular discounts, without advertising, under such arrangements as in the opinion of the Postmaster General will be most advantageous, to the Government.'

"The mandatory terms of Section 3709, Revised Statutes, may not be disregarded by purchasing officers in the absence of authority similar to that contained in the above quoted act of June 30, 1930, in the purchase of spare parts, and in the absence of such authority, you are advised that this office may not approve charges against appropriated moneys for any purchases made under the above referred to or similar contracts entered into without advertising."

The second case has to do with the purchase of standardized units of equipment.

Argument by the Administrative Authority:

"June 10, 1925, ten gasoline engines and outfits were purchased . . . for the use of the United States Coast Guard; . . . bids were not requested . . . and . . . proposal was solicited from one dealer only, for the reason that the particular engines and outfits desired were patented and sold by one dealer only . . .

"The prime function of the Coast Guard stations is to render assistance to vessels in distress and to save life and property from the sea. This service, in the very nature of things, must be rendered under conditions of storm and hazard which create the need therefor. This is a most perilous service at all times, and considerations

of humanity alone demand the provision of the most efficient and dependable equipment obtainable. . . .

"In determining upon a suitable power plant for . . . the standard lifeboat in use at Coast Guard stations, the prime consideration is that it shall not interfere with the functioning of the boat as a lifeboat. Weight must cause no sacrifice of the self-bailing and self-righting features; space occupied must not crowd that essential for crew and passengers; motor operation must be simple, sure, and with all possible safety to crew in every possible position of the boat, even when completely capsized; and the price must be reasonable in order that the greatest number of boats may be powered."

In May, 1917, three (———) motors were purchased for experimental purposes, and in January, 1918, a board was appointed to study the situation. This board recommended that "the standard (———) motor be adopted for use in all motor lifeboats now in construction or about to be constructed. This engine is reasonable in price, has been successfully tried out in several existing lifeboats, is obtainable, spare parts are available, and the engine as a whole possesses more nearly the qualifications laid down by this board in its original report than any other type of engine known to the board, and which is now available."

In April, 1921, a second board canvassed the field and reported that "in whatever type of boat installed the (———) engine has shown reliability in a high degree, combined with a very low upkeep and repair cost.

"It will be seen from the foregoing that every possible effort has been made to secure the best motor available for the purpose desired, that competition has been secured both on a quality and price basis, and that purchase on a price basis alone, and the constant change in hull design and construction which would be necessary to accommodate engines of varying weights, sizes, power, and equipment, is utterly impracticable. At the present time there are over 90 (———) motors in use in the Coast Guard. The engine and boat are so coordinated and standardized that any engine part, shaft, propeller, or fitting, or any item of the boat's outfit, is available for prompt shipment, to be installed usually by the station crew or a district boat repairman, thereby avoiding heavy expense

of contractual repairs and reducing the time a boat may be out of commission to the minimum. This highly desirable condition can be attained only by standardization, and motors are therefore purchased from the only known manufacturer who can meet the requirements. . . .

"With respect to the comment of the General Accounting Office that 'there is nothing in the specifications to indicate that the engine might not have been built by any reputable builder of motor engines,' it is sufficient to state that the product of each manufacturer is covered by patent and can not be reproduced by any other without incurring liability for infringement; nor is it reasonable to assume, if such were possible, that a lower price could be obtained."

Decision by the Comptroller General:

"The facts of record do not disclose, and you do not state, that the particular engines made by the (———) Co. are the only engines that will in fact answer the purposes for which they are required. There is no authority of law for the standardization of such equipment by the Coast Guard, and the fact that numerous tests have been made by boards appointed for the purpose of making investigations with a view of standardization does not operate to take the matter from under the provisions of Section 3709, Revised Statutes, *supra*.

". . . in the purchase of such equipment, bids should be requested on specifications drawn not by designation of a particular make, nor to cover mechanical construction of the engine, but to show the dimensions of the boat, the space available for the installation, the conditions under which it is to be operated, and the performance requirements necessary to meet the needs of the Government."

It appears from the first of the above cases that the purchase by advertisement of standard equipment may not always be advantageous to the Government. The second case not only bears out this contention, but also illustrates the usefulness of proprietary purchase in buying materials for hazardous service.

A third general use for proprietary purchase occurs in the procurement of experimental materials. These are ordinarily used for the purpose of developing data for specifications. It is apparent

that purchase by advertisement may not properly be made without specifications. Therefore, it is axiomatic that experimental materials must be bought by proprietary purchase.

A fourth use for proprietary purchase appears in secret or confidential matters relating to the national defense. It is absurd to think of advertisement in this case.

CONCLUSION.

It is suggested that the present laws providing for proprietary purchase by the Government are inadequate. Provision should be made to permit the proprietary purchase of the following general classes of articles or materials:

1. Standardized equipment, as (*a*) spare parts for machinery units, (*b*) additional material to fit a particular installation, and (*c*) complete units to fit standard installations.
2. Equipment for hazardous or arduous service.
3. Experimental articles or materials.
4. Equipment of a secret or confidential nature as determined by the national defense.

A RELATION OF REVOLUTIONS, PITCH, DIAMETER, AND CAVITATION IN THE MARINE PROPELLER.

By Lieutenant Commander H. H. Curry, U. S. Coast Guard.*

In this article, the author has developed a new series of curves with which to approach the problem of proper propeller design. The method involves an ingenious rearrangement of existing formulae, and nothing new is contributed to basic design. The new factors proposed, however, will undoubtedly prove useful. Figures 1 and 4, in which the new factors are shown in their proper relationships to the basic coefficients have been made larger than the Journal *page size in the effort to clarify them.*

The following is in no respect an original contribution to propeller design. It is merely the algebraic juggling and rearrangement of the criterion formula of Captain Eggert to attack the problem of preliminary design from a little different angle. The accompanying curves of Cd and Cc were constructed in an effort to find the general relations between diameter, pitch, revolutions and cavitation implied by the formula proposed by Captain Eggert for revolutions at which cavitation becomes serious.

The usual restrictions on a preliminary design, especially one having a high-speed length ratio on restricted draft, are a given maximum diameter and cavitation. Effective horsepower is assumed known from model tests or estimates, and a guess is made of thrust deduction and wake factors from block coefficient, lines, position of propeller, and experience. Then useful horsepower (U) calculated by (1).

$$U = \text{E.H.P.} \times \frac{1 - w}{1 - t} \qquad (1)$$

Where w = wake per cent and t = thrust deduction per cent
Speed is assumed known and Va calculated from

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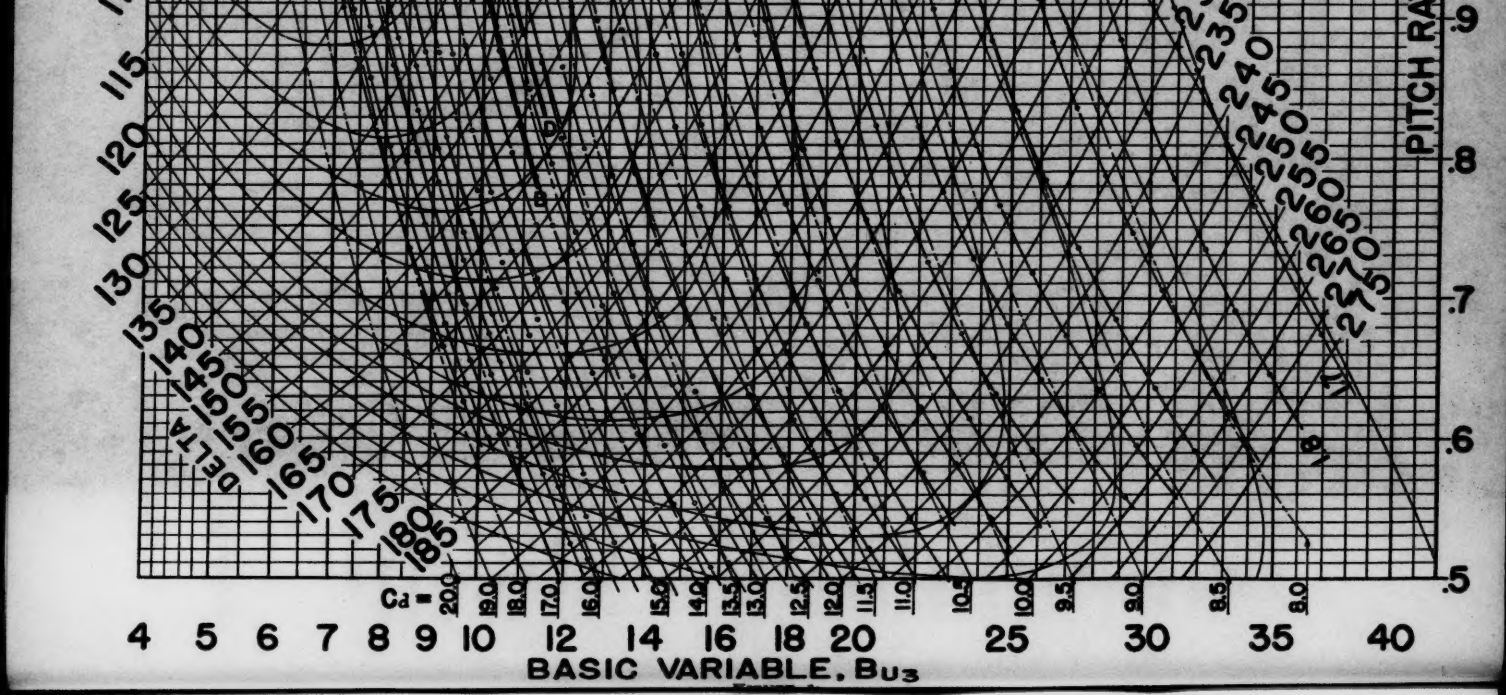
$$Va = V \times (1 - w) \qquad (2)$$

Thus an intelligent guess at the best propeller diameter (d), revolutions and pitch would be based on U, Va, and a limited diameter leaving pitch, revolutions and a possible reduction of diameter as the variable factors. Diameter will probably already be limited to less than that required for maximum efficiency so for the present we will consider U, Va and d given, leaving some possible choice of pitch (p) and revolutions per minute (N). Now as in practically all engineering work a compromise will be desirable. We all realize that low propeller R.P.M. and large diameter are in general favorable to propeller efficiency, while higher R.P.M. means lighter, cheaper propellers, shafting, and gears (which make up a surprising percentage of machinery weights in a light job), and in general, lighter cheaper machinery for equal turbine efficiency, or conversely, perhaps, better turbine efficiency. Comparatively high slips, small diameters, and high R.P.M. can be used in some cases without much greater loss in efficiency than can be gained by a higher wake factor and lighter and more efficient machinery due to the smaller diameter and higher revolutions. However, there is usually a definite limit in this direction other than efficiency for this class of vessel, and that is propeller cavitation.

Apparently one thing needed to get a clear picture of the problem in order to arrive at the best compromise is a convenient graphic representation of just what effect varying pitch, diameter, and revolutions in a particular problem has on propeller efficiency and on cavitating revolutions expressed as a percentage of designed revolutions. Or if there are definite limits to the particular problem it should be possible to show these on a Taylor a-Bu_3 diagram leaving a definite area from which propellers of varying diameter, pitch, and R.P.M., may be selected with the assurance that they will not cavitate excessively at their designed revolutions in so far as the formula now available allows us to predict.

One convenient function would appear to be lines of constant diameter for the particular problem. These may readily be obtained by dividing Taylor's δ function which equals $\frac{Nd}{Va}$ by the


DELTA
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165
170
175
180
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PITCH RA
.9
.8
.7
.6
.5
235
240
245
250
255
260
265
270
275
Cd =
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19.0
18.0
17.0
16.0
15.0
14.0
13.5
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12.5
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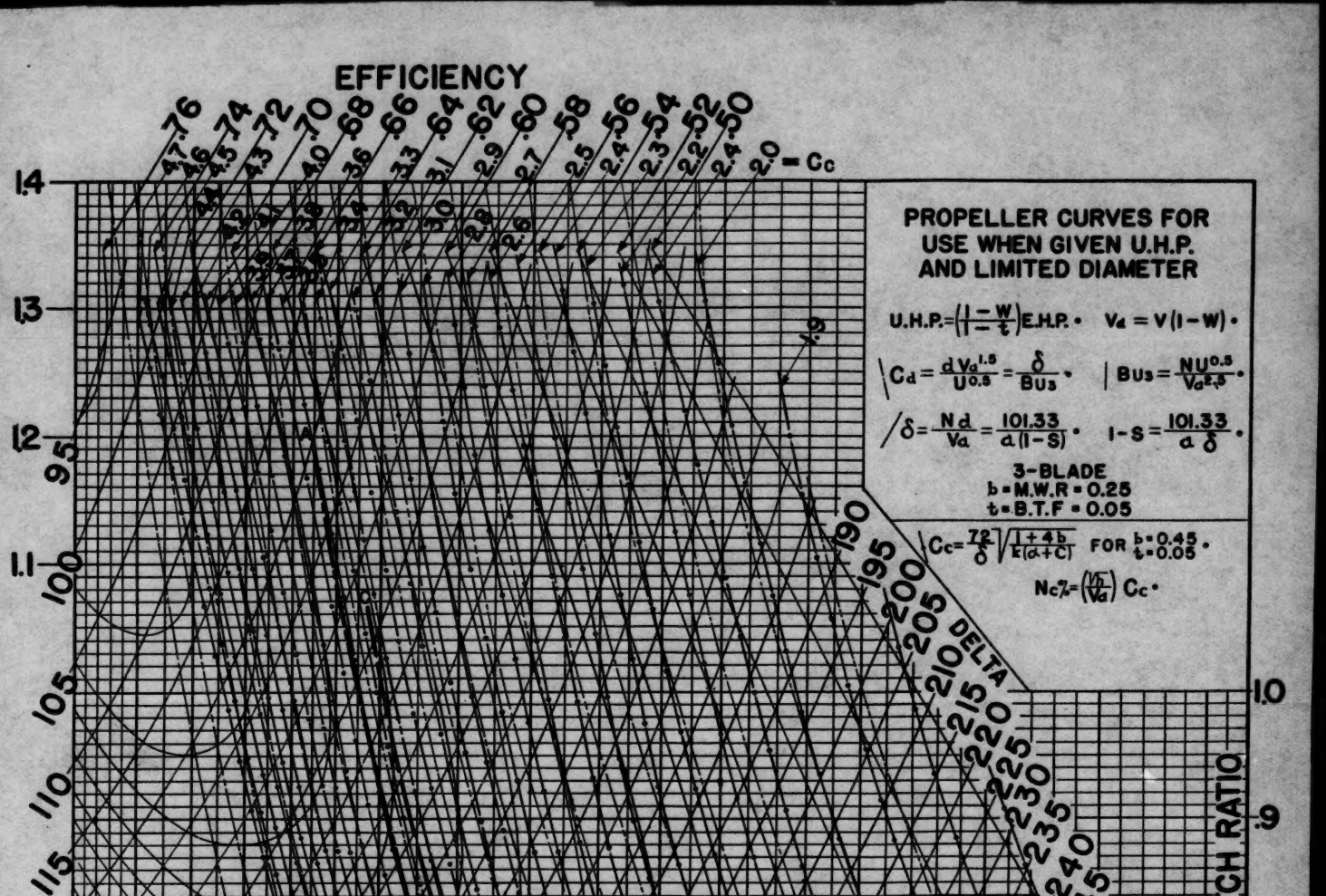
4 5 6 7 8 9 10 12 14 16 18 20 25 30 35 40
BASIC VARIABLE, Bu3


EFFICIENCY
.76 .74 .72 .70 .68 .66 .64 .62 .60 .58 .56 .54 .52 .50
47 46 45 43 40 36 33 31 29 27 25 24 23 22 24
2.0 = Cc
1.4
1.3
1.2
1.1
1.0
.9
95
100
105
110
115
190 195 200 205 210 215 220 225 230 235 240
DELTA
PROPELLER CURVES FOR USE WHEN GIVEN U.H.P. AND LIMITED DIAMETER
U.H.P.=((1−W)/(1−t)) E.H.P. • Va = V(1−W) •
Cd = d Va^1.5 / U^0.5 = δ / BUs • | BUs = N U^0.5 / Va^2.5 •
δ = N d / Va = 101.33 / a(1−S) • 1−S = 101.33 / a δ •
3-BLADE
b = M.W.R = 0.25
t = B.T.F = 0.05
Cc = 72/δ √((1+4b)/(t(a+C))) FOR b=0.45 t=0.05 •
Nc% = (√(Cc/Va)) Cc •
PITCH RATIO

B

V
sl
va
pr
ar
lo
lo
w
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in

c
c
c
c
l
l
f
c
l
i
s
v
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a

Bu_3 function which equals $\frac{NU^{0.5}}{Va^{2.5}}$

$$Cd = \frac{\delta}{Bu_3} = \frac{Nd}{V} \times \frac{V^{2.5}}{NU^{.5}} = \frac{dV^{1.5}}{U^{.5}} \qquad (3)$$

Values of Cd are shown plotted on Figure 1 as diagonal lines sloping down from left to right over a regular a-Bu_3 diagram. The values decrease from left to right, the larger values indicating larger propellers in any particular problem. The factors d, Va and U are the quantities assumed fixed in the problem and are used to locate a line of Cd corresponding to the assumed diameter. Following along this line shows at a glance the variation of efficiency with pitch for this diameter. The revolutions corresponding to any pitch and this diameter can be determined by the corresponding δ value from the formula

$$N = \frac{Va\,\delta}{d} \qquad (4)$$

or for any particular design, assuming constant diameter, N = a constant $\times$ δ. Larger δ values and corresponding lower a values obviously indicate higher revolutions and less pitch as we follow down the constant diameter contours. Or conversely, if revolutions are given, the δ value is fixed and the intersection of the δ line with the Cd line corresponding to the assumed d, Va, and U, fixes the required pitch ratio. Also if we have used the maximum diameter allowable we know our only choice lies along this Cd line or on smaller values to the right of it (less diameter). To investigate the effect of changing diameter but keeping N constant, follow up or down a vertical line corresponding to a constant value of Bu_3 going up from any point corresponding to smaller diameter and greater pitch, or conversely, down to larger diameters and less pitch.

It may be noted that diameter has a greater effect than N on efficiency throughout the usually used areas whereas varying N on a constant diameter has a surprisingly small effect over a considerable range about the point of maximum efficiency. This gives a fair picture of the effects of varying N, d, and p. These lines were calculated for Taylor's standard 3-bladed propellers of ellip-

tical blade outline, .25 m.w.r. and .05 b.t.f. Apparently variations in blade width or thickness cause no important changes in the values of N, p, and U and may be corrected for by data given in Taylor's " Speed and Power of Ships."

A general graphic representation of the effect of cavitation as a limit in the design, as shown by the formula devised by Captain Eggert for revolutions per second at which cavitation becomes serious, is not as practicable because of the much greater effect of changes in blade width and thickness ratios as shown by the effect of the factors $(1 + 4b)$ and c in equation (11). However, where cavitation is a serious limit, a very wide, thin blade is assumed and with these variables assumed replaced by an elliptical blade of .45 m.w.r. and a b.t.f. of .05 the solution becomes more feasible if less general.

This formula is:

$$v^2 = k\,\pi^2\,d^2_{.9}\,n^2 = 10.7h\,\frac{1 + 4b}{a + c} \qquad (5)$$

where v = velocity of water past a blade section at .9 radius

$$s = \text{slip in } \% \text{ of the propeller} = 1 - \frac{101.33}{a\,\delta}$$

$a_{.9}$ = pitch ratio at .9 radius.

$d_{.9}$ = diameter at .9 radius

$$a = \frac{\frac{a_{.9}}{\pi} \times \frac{s}{2}}{1 + \frac{a^2_{.9}}{\pi^2}\left(1 - \frac{s}{2}\right)} \qquad (6)$$

$$k = 1 + \frac{a^2_{.9}}{\pi^2}\left(1 - \frac{s}{2}\right)^2 \qquad (7)$$

c = blade thickness ÷ blade width at .9 radius (8)

h = submergence of propeller axis in feet + 33 feet (atmospheric head)

Equation (5) may be rewritten as

$$n = \sqrt{\frac{10.7\,h\,(1 + 4b)}{k\,(a + c)}} \Big/ \pi\, d_{.9}$$

where n = revolutions per second at which cavitation becomes serious (9)

c for an elliptical blade tapered in section to the edge as shown in Figure 2, will be found from the equation of an ellipse to be $.14\,\frac{b.t.f.}{b}$. When blade tapers in thickness as shown in Figure 3, to 0 thickness at 1.1 radius extended, c = approximately $.25\frac{b.t.f.}{b}$

b in each case is mean blade width ratio and b.t.f. is the blade thickness ratio expressed as a fraction of propeller diameter d, not $d_{.9}$.

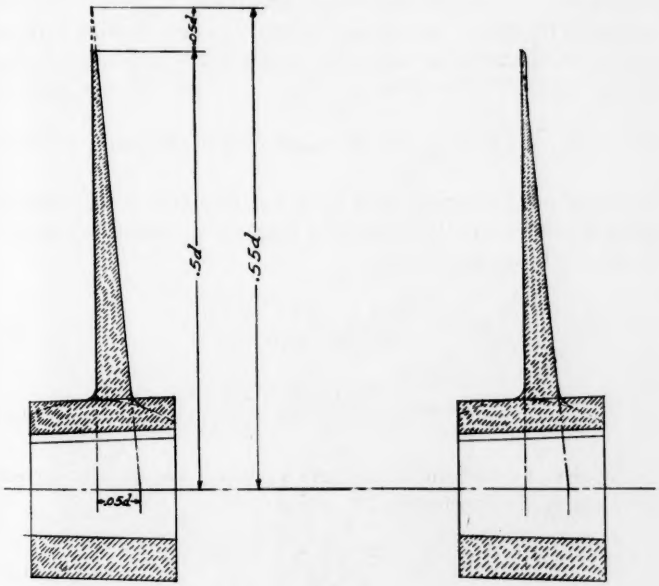


FIG.-3 FIG.-2

Leaving out of the discussion the point of whether or not this is merely " formula cheating " to obtain a higher calculated cavitating R.P.M. and whether or not the formula will hold for blades of the width assumed, we will take a blade of the type shown in Figure 2 with a m.w.r. of .45 and b.t.f. of .05 giving c a value of $.14 \times \frac{.05}{.45}$ $= .0155$. Substituting this in the formula gives this formidable looking equation:

$$Nc = 60\sqrt{\frac{10.7\ h\ (1 + 4\ b)}{1 + \frac{a^2}{.81\pi^2}\left(1 - \frac{s}{2}\right)^2 \frac{\frac{a}{.9\pi} \times \frac{s}{2}}{1 + \frac{a^2}{.81\pi^2}\left(1 - \frac{s}{2}\right)} + .0155}{.9\ d\ \pi}} \qquad (10)$$

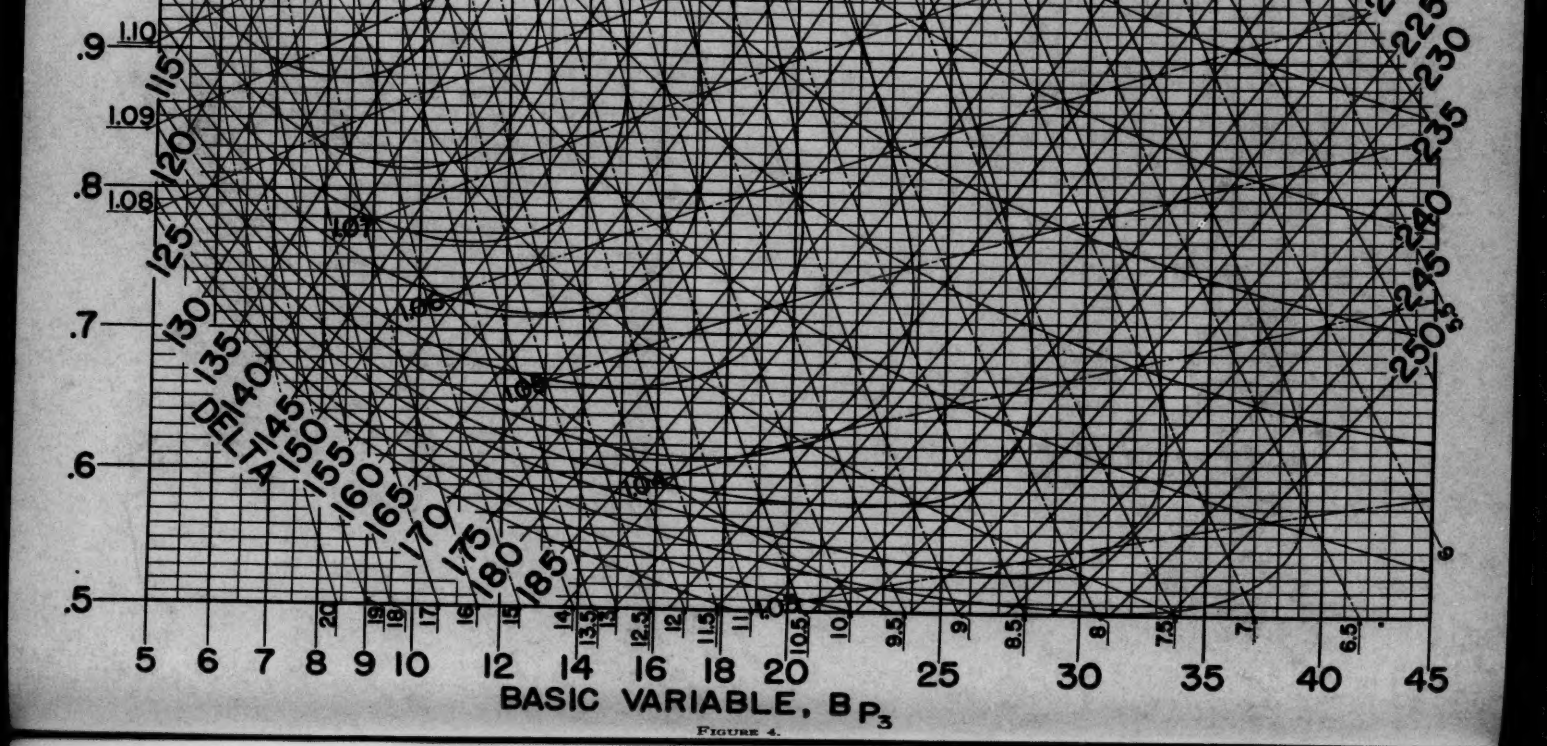
In using this formula to estimate revolutions at point of serious cavitation the writer was most consistent in either making careless errors in arithmetic or neglecting to use pitch ratio at .9 radius instead of pitch ratio of the propeller, so an attempt was made to substitute $\frac{a}{.9}$ or 1.111a for the value of a at .9 radius, which is allowable for a constant pitch propeller, then collect the constant terms which reduces the formula to (11), or for the blade assumed ($t = .05$, $b = .45$) to (12).

$$Nc = \frac{69.4}{d}\sqrt{\frac{h\ (1 + 4\ b)}{k\ (a + c)}} \qquad (11)$$

$$Nc = \frac{69.4\ \sqrt{h}\ \sqrt{2.8}}{d\ \sqrt{k\ (a + .0155)}} \qquad (12)$$

As Nc given by the formula averages 5 per cent low we may correct by changing the constant to 72, giving

$$Nc = \frac{72\ \sqrt{h}\ \sqrt{1 + 4\ b}}{d\ \sqrt{k}\ (a + c)} \qquad (13)$$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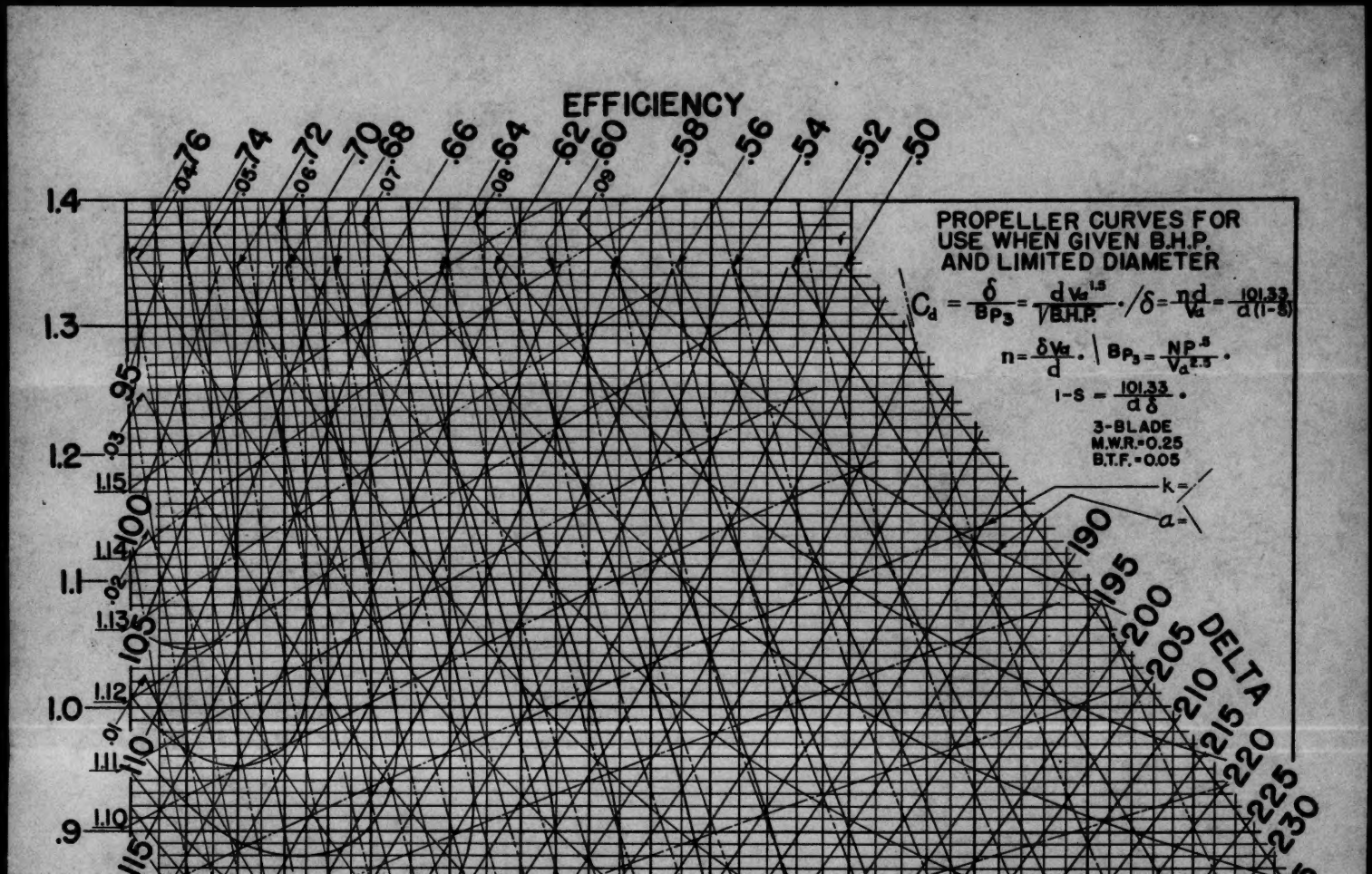
BASIC VARIABLE, B_{P_3}

FIGURE 4.


EFFICIENCY
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1.3
1.2
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.95
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DELTA
PROPELLER CURVES FOR USE WHEN GIVEN B.H.P. AND LIMITED DIAMETER
$C_d = \frac{\delta}{BP_3} = \frac{d\,V_a^{1.5}}{\sqrt{B.H.P.}} \cdot \quad \delta = \frac{nd}{V_a} = \frac{101.33}{d(1-s)}$
$n = \frac{\delta V_a}{d} \cdot \quad BP_3 = \frac{NP^{.5}}{V_a^{2.5}} \cdot$
$1-s = \frac{101.33}{d\,\delta} \cdot$
3-BLADE
M.W.R.=0.25
B.T.F.=0.05
k=
a=

For a given blade proportion, diameter, and submergence this has only α and k as variables and both α and k are functions of slip s and pitch ratio a. Also each point on Taylor's a-Bu_3 diagram represents a definite value of both slip and a, therefore corresponding values of α and k may be plotted as contours as has been done by Mr. Paul G. Tomalin of the Coast Guard as shown in Figure 4. This is plotted on a and Bp_3 together with the usual contours of efficiency and δ in Figure 5. As the same value of δ and a means the same slip whether plotted to a base of Bu_3 or Bp_3, only the abscissa of the particular point varying as the square root of the efficiency in the two diagrams, Figure 5 may be used for either Bu_3 or Bp_3 by selecting α and k values corresponding to the desired δ and a values.

As the relation between a, δ, and s on Taylor's diagram is given by the equation

$$(1 - s) = \frac{101.33}{a\delta} \tag{14}$$

an attempt was made to express α and k directly in terms of a and δ, but this leads to cumbersome expressions of no apparent value, so the most convenient method of estimating Nc apparently is to select the values of α and k from the diagram, calculate c, then substitute in (13), or slip may first be calculated from equation (14) then α and k calculated from equations (15) and (16) then substituted in (13).

$$\alpha = \frac{.1766\, a\, s}{1 + .125\, a^2 \left(1 - \frac{s}{2}\right)} \tag{15}$$

$$k = 1 + .125\, a^2 \left(1 - \frac{s}{2}\right)^2 \tag{16}$$

Dividing (13) by (4) gives cavitating R.P.M. in terms of designed R.P.M.

$$\frac{Nc}{N} = \frac{72}{d}\sqrt{\frac{1 + 4\,b}{k\,(\alpha + c)}} \times \frac{d}{Va\,\delta} = \frac{\sqrt{b}}{Va} \cdot \frac{72}{\delta}\sqrt{\frac{1 + 4\,b}{k\,(\alpha + c)}} \tag{17}$$

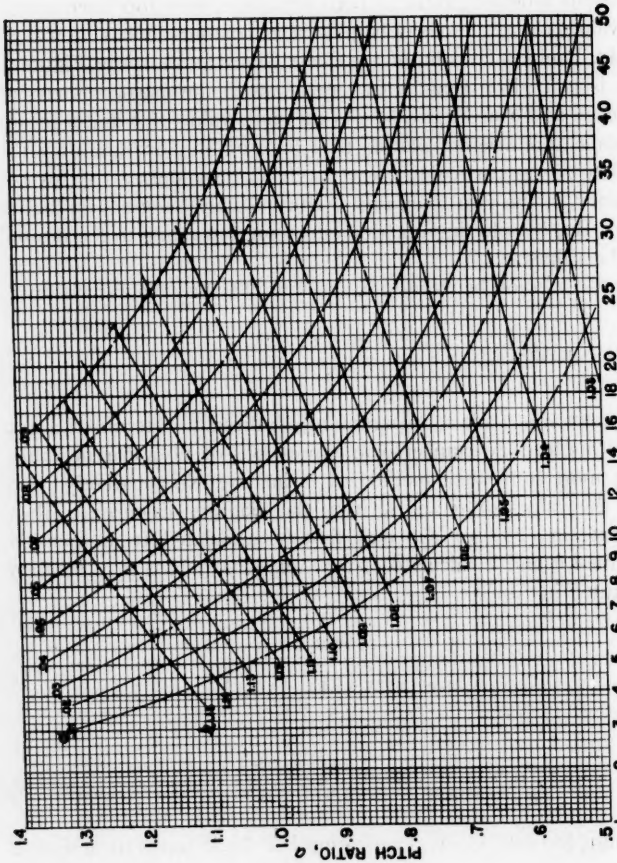
PITCH RATIO, σ
BASIC VARIABLE, B_{P_s}
CONTOURS OF δ_b AND α IN EGGERT'S CAVITATION FORMULA

FIGURE 5.

For a definite value of b, b.t.f., and blade shape we have seen that each point on Admiral Taylor's a-Bu_3 diagram corresponds to a definite value of the function $\frac{72}{\delta}\sqrt{\frac{1+4b}{k\,(a+c)}}$. Contours of these values (Cc) for b.t.f. = .05, and m.w.r. = .45, are shown plotted on the a-Bu_3 diagram in Figure 1.

We are now ready to examine the effect of changes of diameter, pitch, and revolutions on cavitation in any particular case. For the propeller to reach its designed R.P.M. without serious cavitation $\frac{Nc}{N}$ must equal or exceed 1, therefore Cc must equal or exceed

$$\frac{Va}{h^{.5}} \qquad (18)$$

according to the cavitation criterion formula for the type of blade assumed for this discussion.

We have found that for a limited diameter we must choose the propeller from the area to the right of the Cd line representing this maximum diameter with the power and Va of the particular problem. We now find that to avoid cavitation we must choose the propeller from the area to the left of the Cc line determined by the Va and submergence of the problem. If there is no space between the two lines according to the formula, no propeller can be designed with the assumed blade width and thickness and specified diameter which will give the required thrust with the Va of the problem without cavitation.

Over the usually used area shown in the figures it appears that for a specified thrust and speed, diameter is the most important factor affecting cavitation and that on a given diameter the higher pitch ratios and lower revolutions are more favorable, but that the best pitch ratio for both efficiency and cavitation goes down as the loading goes up.

Following up a constant diameter line also nicely demonstrates that in general if a propeller be designed to give a specified thrust at a definite Va and R.P.M. at maximum efficiency another pro-

peller having greater pitch but lower R.P.M. may be selected giving slightly higher efficiency on the same diameter. In other words, for a propeller selected for the maximum efficiency at a given Bu_3 value, there is a propeller of the same diameter but greater pitch and lower revolutions which has an efficiency greater than the first under identical conditions of thrust, Va, and d. However, this second propeller is not as efficient as the optimum diameter propeller for the lower Bu_3 value.

To repeat in brief: Given a maximum d with a Va and U pick a maximum diameter contour from equation (3) $Cd = \frac{dVa^{1.5}}{U^{.5}}$.

Pick a limiting cavitating contour from equation (18). The possible propellers, if any, lie between these lines. Make what appears to be the best compromise betwen N and e in this area, in general favoring higher δ values.

The percentage of designed speed at which cavitation occurs under the specified thrust and Va is given approximately by

$$100 \frac{h^{.5} Cc}{Va}.$$

Suppose we have given an 185-foot hull estimated to require around 2000 E.H.P. for bare hull. It is desired to make 25 knots, using a single screw if practicable, of not over 6.5-foot diameter with 18-inch tip submergence. What pitch and R.P.M. is preferable? We will add say 8 per cent for appendages. Suppose we know of no tests of a similar hull at around this speed-length ratio, so after looking over conflicting wake factor data, estimate the wake from the formula

$$w = \frac{.2 \times L^{.25}}{V^{.5}} \text{ or } \frac{.2 \times 185^{.25}}{25^{.5}} = \frac{2 \times 3.688}{5} = 14.75 \text{ per cent}$$

wake fraction.

As we are feeling optimistic, we will guess the thrust deduction factor at 10 per cent, then useful H.P., $U = 2000 \times 1.08 \times \frac{(1-15)}{(1-10)} = 2040$ H.P.

$Va = 25 \times (1\text{-}15) = 21.3$ knots.

$$Cd = \frac{d\ Va^{1.5}}{U^{.5}} = \frac{6.5 \times 21.3^{1.5}}{2040^{.5}} = \frac{6.5 \times 98.3}{45.17} = 14.2$$

Now we know our propeller must be on Cd = 14.2 (line A-B of Figure 1) or on some line to the right of this corresponding to a smaller diameter.

To avoid cavitation with a blade of .45 m.w.r. and a b.t.f. of .05 we are limited to a minimum value of Cc of

$$\frac{Va}{h^{.5}} = \frac{21.3}{\sqrt{3.25 + 1.5 + 33}} = \frac{21.3}{37.75^{.5}} = \frac{21.3}{6.144} = 3.46 \text{ (line}$$

C — D of Figure 1).

As C-D is to the right of A-B and approximately parallel to it, apparently a propeller of 6.5-foot diameter will produce the required thrust at this speed without serious cavitation and allow some choice in pitch and R.P.M. Little change in efficiency is indicated between a values of say .96 and 1.2 but as a high R.P.M. is desirable, we will try .96. The δ value is 140. Then $N = \frac{Va \times \delta}{d} = \frac{21.3 \times 140}{6.5} = 458$ R.P.M., but suppose it is desired to use machinery already available with a top speed of 450 R.P.M. then $\delta = \frac{450 \times 6.5}{21.3} = 137.5$ giving a corresponding a value of say .98 for 450 R.P.M. e = about 68.8 per cent $\times$ .97 correction for the wide blades, say 66.8 per cent. $2040 \div .668 =$ 3050 S.H.P. required.

Now to calculate the cavitating R.P.M. to check the approximation from the curves and to demonstrate the use of the simplified formula. The factors α and k may be calculated as follows:

$$1 - s = \frac{101.33}{.98 \times 137.5} = .752,\ s = 24.8 \text{ per cent},$$

$$s/2 = 12.4. \quad \alpha = \frac{.1766\ a\ s}{1 + .125\ a^2}\ (1 - s/2)$$

$$a = \frac{.1766 \times .98 \times .248}{1 + .125 \times .98^2 \times .876} = \frac{.043}{1 \quad .125 \times .9604 \times .876} = \frac{.0431}{1.105} = .039$$

$$k = 1 + .125\, a^2 (1 - 5/2)^2 = 1 + .125 \times .98^2 \times .875^2 = 1.094$$

$$Nc = \frac{72\, h^{.5}\, \sqrt{1 + 4\, b}}{d \quad (a + c)} \qquad \text{where}$$

$h^{.5} = 6.144$, $b = .45$, $d = 6.5$, $k = 1.095$,

$a = .039$ $c = .0155$

$$Nc = \frac{72 \times 6.144 \times 1.673}{6.5\ 1.094\ (.039 + .0155)} = \frac{72 \times 6.144 \times 1.673}{6.5 \times .2441} =$$

466 R. P. M.

The use of a constant c factor may lead to a wrong impression of the great importance of blade thickness in affecting the calculated speed at which cavitation begins, as shown by the formula, but the object of the study was to form a general picture of the effect on cavitation of varying pitch, R.P.M., and diameter in any particular problem and the only practicable way was to eliminate c as a variable.

As the c value is so related to strength requirements, blade shape, and type of section, a series of such Cc diagrams based on various c values might be of value for actual design work, however, if this limitation is realized, then the use of this Cc diagram based on .05 b.t.f. and a *c* value of .0155 may be used to pick a point about which other propellers may be investigated more accurately by calculation.

Opinions differ as what may be considered " serious cavitation " and in using this term the wording of Taylor's Speed and Power of Ships was used. It has been suggested that the term " beginning of cavitation " might be more accurate for the R.P.M. indicated by equation (12). This R.P.M. is not considered an absolute limit on design, but certainly working to the right of the corresponding Cc line is a very undesirable compromise, which should be avoided if practicable.

SYMBOL KEY.

α equals circular measure of 1/2 slip angle, equals

$$\frac{\frac{a_{.9}\, s}{2\pi}}{1 + \frac{a^2_{.9}}{\pi^2}\left(1 - \frac{s}{2}\right)} = \frac{.1766\ a\ s}{1 + \frac{a^2}{8}\left(1 - \frac{s}{2}\right)}$$

a pitch ratio equals p/d

b (m. w. r.) = mean width ratio = mean width of developed blade ÷ diameter of propeller.

c thickness ratio at .9 radius equals $\frac{\text{thickness}}{\text{chord}}$ at .9 radius.

Cc equals $\frac{72}{\delta}\sqrt{\frac{1 + 4\ b}{k\ (d + c)}}$

Cd equals $\frac{\delta}{BU} = \frac{d\ V^{1.5}}{U^{.5}}$

d diameter in feet

δ equals $\frac{Nd}{Va}$

e efficiency in per cent

h submergence of propeller in feet plus 33

k function used in cavitation formula equals

$$1 + \frac{a^2_{.9}}{\pi^2}\left(1 - \frac{s}{2}\right)^2 = 1 + \frac{a^2}{8}\left(1 - \frac{s}{2}\right)^2$$

L length of vessel in feet

N R. P. M. of propeller equals $\frac{\delta\ Va}{d}$

Nc R. P. M. at which cavitation becomes serious

n R. P. S. of propeller

p propeller face pitch in feet

s= slip in per cent equals $1 - \frac{101.33}{a\,\delta}$

b. t. f. = blade thickness factor in terms of diameter

U= useful H. P. = E. H. P. $\times \frac{1 - w}{1 - t}$

V= speed in knots of hull

Va = V $\times$ (1 — w) speed of advance of propeller

w = wake in terms of speed of hull

BU_3 Taylors Basic Coefficient in terms of useful power for 3 bladed propellers equals $\frac{NU^{.5}}{Va^{2.5}}$

BP_3 Taylors Basic Coefficient in terms of brake H. P. for 3 bladed propellers, $\frac{Bu\ 3}{\sqrt{2}}$

THE

ANNUAL BANQUET

OF THE

AMERICAN SOCIETY OF NAVAL ENGINEERS

HELD AT

THE WILLARD HOTEL

WASHINGTON, D. C.

APRIL 15, 1937

THE 1937 BANQUET.

The annual banquet of the Society was held in the main ballroom of the Willard Hotel, Washington, D. C., on the evening of April 15, 1937. Although the date had been selected some time before, the vagaries of a Washington climate held back the blossoming of the Japanese Cherry Trees around the tidal basin, so that they reached their full glory during the banquet week, and many an out-of-town guest was able to view this seasonal display for the first time.

The roster of members and guests shows that nine hundred and seventeen persons assembled at the ninety-two tables spread between the speakers' dais and the Navy Band, to honor the Society by their presence, and thus to set a new high in the annual attendance on these affairs.

The Committee in Charge was fortunate, indeed, in its selection of speakers. Each of these in his own way held the interest and attention of the large gathering, and each fitted neatly into the program ably engineered by a young but extremely competent toastmaster, Commander Richard A. Bates, U. S. Navy. With the dinner well along, the Toastmaster settled his audience, and introduced as the first speaker of the evening, Rear Admiral Alfred W. Johnson, U. S. Navy, Member of the Navy's General Board, and the President of the American Society of Naval Engineers. Admiral Johnson's speech of welcome to the members and guests was brief and graceful, and went somewhat as follows:

It is an unusual pleasure to welcome this great gathering of members, associates, and friends, at this reunion marking the 49th year since the founding of the American Society of Naval Engineers. It is gratifying also to observe that the number attending the annual dinners of the Society grows larger, and not smaller, with the passing of time.

To all who are here tonight I extend hearty greetings, and in behalf of the members present wish to express to our distinguished

guests and numerous friends the real pleasure we feel in having you with us this evening. We wish especially to welcome the new members and associates who have joined us during the past year, and who are with us for the first time, as well as those of long standing who come from near and far away places, to renew old associations here tonight.

I have a message of greeting which I want to read to you, from a man who always has manifested great personal interest in our Navy, and who has done much to keep it efficient. It is a note from the President of the United States.

April 7, 1937.

My dear Admiral Johnson:

Upon the occasion of your annual banquet, may I extend my warm greetings to the American Society of Naval Engineers. Please express to the members my appreciation of the worthwhile achievements of the Society and extend to them my best wishes for continued progress and even greater achievement.

With every good wish,

Very sincerely yours,

FRANKLIN D. ROOSEVELT.

In these times of political and social unrest and difficult economic problems, it is a good thing to set aside one evening each year, as we do tonight, and unite with friends who have common interests in engineering fields where we can forget such troubles. Here, too, let us also forget, at least for a little while, the legal and contractual difficulties that sometime trouble us.

So, while the evening is still young, let us all join with each other and have a good time.

Admiral Johnson was followed by the Honorable Charles Edison, the Assistant Secretary of the Navy, who devoted his address to the value of research in furthering Naval development. An able son of a distinguished father, the Secretary's quick grasp during a short tenure of office of the complex scheme of activities by which the Navy keeps pace with rapidly advancing industrial and scientific progress, was noted by all, and his remarks were received with deep interest and attention. He spoke, in part, as follows:

An able and efficient Navy must constantly concern itself with the manifold scientific developments of a rapidly changing world. Technological development has been spectacular during the past few years, and the Navy, perhaps the largest organization requiring highly developed and specialized equipment, has adopted a progressive program of direct and cooperative research in engineering development. This has been necessary to enhance the military efficiency and usefulness of the Fleet.

The principal function of research in the United States Navy is to assist in carrying out one of the general naval policies which is "to create, maintain and operate a Navy second to none." In following this basic policy many functions are performed which contribute to the welfare of the country during peace time.

Progress in the Navy is sustained by the intensive training and maintenance of the Fleet and its individual ships in a "readiness for war" condition; by the constant study on the part of its officer personnel of the lessons of naval history; and by using new strategical and tactical methods resulting from the application of scientific research.

In personnel, the Navy progresses by constant improvement in the education and training of its officers and men. To this end it uses psychological, physiological and medical tests developed by the research in these sciences.

In material, progress is made by research and testing of new products to determine their desired characteristics and adaptability for Naval use. New features of design are continuously investigated for possible application. As a result of such research, investigations and tests, each new naval vessel built represents a marked advance over predecessors of its class.

The modern man-of-war is the acme of technological development, embodying in its most concentrated and useful form the accumulated experience of nearly every branch of human endeavor. Moreover, since all fleets are potentially competitive in nature, it becomes quite necessary that the best and most highly developed equipment be supplied to maintain them. It is important also that the personnel of the Navy be efficient, progressive and intelligent in order that our fleet may gain the greatest benefit from superior ships and equipment.

In order to preserve a growing healthy organization and to maintain productiveness, American Industry has found, again and again, that systematic research in laboratories especially provided for the purpose is absolutely essential. Profiting by this experience and that of the World War, research laboratories have been established within the Navy. These are directed "to increase the safety, reliability, and efficiency of the fleet by the application of scientific research, and laboratory experimentation to Naval problems."

It has been my distinct privilege and pleasure to inspect, during the past two months, most of the Navy's research and experimental stations. As a comparative "new comer" to the Naval establishment I was particularly pleased to see the large scope of development these agencies covered. The work is done with a thoroughness and skill commensurate with the best scientific practices in the United States.

These agencies operate under several different Bureaus according to the type of work which is undertaken. For example, in addition to several routine testing organizations, there are five distinct groups of laboratories for applying experimental, scientific methods to naval problems.

Under the Bureau of Navigation, the Naval Observatory and Hydrographic Office conduct important Astronomical and Hydrographic investigations.

Under the Bureau of Construction and Repair the Ship Model Basin carries on research on ship forms, structures and propellers.

The Bureau of Aeronautics sponsors a great deal of research work in several governmental and commercial laboratories.

The Bureau of Engineering maintains the Engineering Experiment Station, the Material Laboratory, the Naval Boiler Laboratory and a nucleus for basic scientific investigation at the Naval Research Laboratory. Each organization, however, undertakes problems for the entire Navy.

The Navy cooperates with other laboratories of the Government such as the National Bureau of Standards, U. S. Bureau of Mines, the Chemical Warfare Service, and the ever important National Advisory Committee for Aeronautics. It further cooperates with many excellent industrial and university laboratories of the country, many of which have contributed much to the National security.

The excellence of modern naval equipment is largely due to the assistance of American industry in the improvement of methods and equipment through scientific investigation. Industry needs the Navy and the Navy needs industry.

There is no need to stress before this body the part which research plays in modern industry. Research carefully guided by able and competent scientists leads to new processes, new products, or to great improvement in present products and methods. An exactly parallel situation exists in the Navy and constant effort to study and improve has led to great advances in Naval equipment. Many of the more recent fruits of scientific investigation carried on by the Navy cannot be discussed here, but it may be of interest to at least mention a few examples.

The Navy's contributions to radio communication have been many and outstanding. The Research Laboratory pioneered in the exploration of the great possibilities of high frequency transmission. It built the first high power crystal controlled equipment for this type of service. It first formulated certain basic laws controlling transmission and made many other important advances which have contributed to the efficiency of the Fleet and its economy of operation. This laboratory has also made outstanding contributions to the scientific study of the earth's ionized outer atmosphere.

It is not generally known that the Naval Observatory, through eclipse expeditions and theoretical investigations, has contributed more to man's knowledge of the sun's chromosphere than any organization on earth.

Investigations looking toward the improvement of the ships themselves are constantly being carried on. For example, to make most effective use of the high-efficiency Navy power plants, ships' propellers must efficiently transmit more and more power. The Ship Model Basin is conducting elaborate experiments on the design of propellers. These researches are endeavoring to evolve types of propellers which will transmit greater power than existing types, before the ultimate limitation imposed by cavitation is reached.

In order to verify the theoretical and small-scale tests upon which ship design has heretofore been based, the Bureau of Construction and Repair strained and stressed to destruction two complete destroyer hulls, simulating the hogging and sagging conditions

which are the limiting conditions assumed in ship design. These full-scale experiments on the destroyers *Preston* and *Bruce* are destined to take their place among the classical experiments in the history of naval architecture.

Similarly, strength tests on thin reinforced shells subjected to external pressure, representing the strength hulls of submarines, have been made by the Model Basin to verify and define the limits of the application of the formulas used in the design of submarines. The results of this work have been of great value to the Navy and to industry as well.

The Bureau of Aeronautics, through developmental contracts with a large commercial organization, stimulated the production of a satisfactory radial air-cooled airplane engine which has been of inestimable value to aviation.

Important contributions to the performance of steam boilers have been made by the Naval Boiler Laboratory and the Engineering Experiment Station. Extensive studies have been made of the properties and circulation of boiler water in the high power boilers. The study resulted in improvements in design and some reduction in the overall weight and space requirements. The use of higher temperatures and pressures in recent propelling machinery installations have required research to determine suitable materials.

The Engineering Experiment Station has also been engaged in making a scientific study for reducing the noise level of various machinery units on board ship. High noise levels are objectionable, both from the standpoint of tactical and personnel efficiency. Design modifications and the application of the most suitable sound absorbing materials have proven most effective in noise reduction. The Engineering Experiment Station tests all new types of Diesel engines before final approval for purchase. This laboratory also entered the field of research in its Diesel fuel oil investigation. After two years' work, specifications for an all-purpose (except aviation) Naval Diesel fuel oil have been prepared.

Very difficult Ballistic Problems have been studied by the scientists at the Naval Proving Grounds, and much valuable information regarding the resistance of armor to penetration has been obtained. Other studies of guns and projectiles have been of value.

As a further example, one may mention the important program carried on by the Naval Research Laboratory in an attempt to im-

prove the mechanical equipment of the Navy. An experimental foundry is carrying on studies of the contraction, and strength, of newly cast hot steel. This has for an ultimate objective the preparation of quantitative rules to be applied in the design of cast steel objects and patterns and improvements in present foundry practice.

Basic methods for examining thick metallic sections for soundness by means of radium have been worked out and made available to industry. Other methods for locating defects employing electromagnetism and high frequency sound have been worked out and offer considerable promise.

It is evident from the foregoing illustrative examples that the Navy is actively pursuing experience and definite knowledge of its peculiar requirements through the agency of scientific research. It seems essential that research be carried on in an aggressive manner in peace time in order that its fruits may be available in a national emergency.

Many Naval problems are in those fields where broad commercial application does not exist, and the Navy must look to itself to carry out their solution. One may recognize also that an active research program in any organization is the best protection against waste and misdirection.

Finally, although the immediate function of research is to carry out the stated policy, yet in a large sense the prime function of scientific research in the Naval establishment is to guarantee National Security.

Mr. President, it has been a very real and genuine pleasure for me to meet here tonight with you and the members of the American Society of Naval Engineers. Your organization and your annual meetings are indeed splendid media for the development of that mutual understanding which is so essential to real achievement in any field of human endeavor. You have provided a common ground upon which industry and the Navy can meet to discuss common problems so that our common objective—the preservation of peace through adequate National Defense—can best be served.

The next speaker was Rear Admiral Thomas C. Hart, U. S. Navy, Chairman of the General Board of the Navy. With the great shipbuilding program now underway, Admiral Hart felt that

it was timely to discuss the functions of the General Board as these concern and influence Naval shipbuilding, and he pointed out to an intent audience very clearly the delicate balance which the Board must maintain in the preliminary design of a fighting ship between all the complex characteristics and the conflicting interests which go into its making. He spoke, in part, as follows:

I note that I am introduced as belonging to a board, one of those things sometimes described as being long, narrow, and so forth, and you may be wondering what board *this* is. Those having the after dinner radio habit will have heard of us because a certain radio orator has been having a good bit to say that makes the General Board of the Navy stand out. We must by now be either famous or notorious, but I will talk about it briefly.

My Board was built up by Admiral Dewey, who was its head for many years, up to his death. During his time, the Navy had practically *no* General Staff and as the General Board's work grew it came to take on the staff function of advising the Secretary of the Navy in various matters of large import;—it has *never* had any direct administrative or executive function. With the advent of a General Staff, which the Navy possesses in its highly important Office of Operations, formed over twenty years ago, the General Board continued in existence and still works for and reports direct to the Secretary of the Navy.

The number of the Board varies. Just now it has four officers of flag rank and two of command rank and it has always comprised a large sum total of general and varied experience. You are all familiar with the character and place of the Genro in Japanese affairs. Well, the younger element of the Navy calls us that, the elderly statesmen, with decided emphasis upon "elderly." However, the Board works upon any problem which the Secretary gives it, and we suspect the young men of the Department are persuading the Secretary to pass to us certain hot questions which they wish to rid themselves of. But, anyhow, we have—and now I come to what touches many of this audience—the continuous and all-important subject of ships.

The General Board periodically recommends to the Secretary the naval building programs and the general characteristics which

the various kinds of ships on approved programs should have. That is a highly important subject on which work progresses quite continuously. In qualification for the duty we have in the main only the background of varied experience. We have to keep said background far enough *back* and to be cognizant of what *is*, today, in the way of technical development of war material and also the potentialities of recent invention. We obtain our information from wherever it can be found, call upon anyone's subordinate for work, study, and opinions, go outside the naval service for the same if we so see fit and always use the quickest and most direct methods in search of the facts and the truth. Conversely, we are always open to anyone who wishes to bring us thoughts and opinions. In the end, the purpose which the Board serves amounts to bringing into the best possible balance the more or less conflicting elements of design to the end of coming out with harmonious combinations. All technicians and specialists are enthusiasts and conceivably can run wild. For instance, with a free rein the radio engineers could fill the ship with their equipment, the doctors could have her come out too much a hospital ship, and so on. Someone has to hold the ultimate purpose in mind, someone needs keep in view the reason for it all and see to it that our ships have *balance*. That is where the General Board strives to be useful.

But, oh, the complications that attend preparation for the national defense. The whole world is aware of the complexity of modern warfare, on land at least; and I really think it is even worse at sea. It makes one long for the good old days;—not so long ago it was all so nice and simple,—propulsion by sail, poetic, practice of the fascinating art of the simple sailor, no radio to bother one, and in battle rounding up to within a couple of city blocks and fighting it out like gentlemen. All *so* nice and simple, leisurely, serene, little strain on the nerves or intellect, no grease and oil about, a gentleman's job then for my profession. And now we fight at ranges such that we can scarcely see each other, have little leisure, and instead work day and night in the effort to keep efficient in the use of the multitude of complex machines and equipment which the inventors, research men, and engineers turn out for us to fight with. Besides fighting on the surface of the sea, we are now under it in submarines and over it in aircraft. Three dimensions now,

and first we know the engineers will make us fight in a *fourth* dimension! But we must have our inventive engineers.

Now for instance;—ships which we build today have main power plants that, within the same space and on the same weight, have three times the power of similar ships which we built less than twenty years ago. And the engineers are still at it, for almost before we get the aforesaid development digested we find that they are soon coming out with a much greater concentration in power, still higher pressures and temperatures, and perhaps boilers of large capacity with not much more water contained in them than each of you uses for shaving every morning. That example is just to illustrate the march of progress. The country's engineers in general contribute, and many of them are here tonight. I'm glad to say that the Navy has some of its own who are in the movement themselves. And whoever does or has done the work there seems no doubt that solving the Navy's problems has contributed largely to the engineering knowledge and experience of the nation.

So much for speaking in my announced capacity. Quite in my private capacity and as expressing no ideas whatever other than my own, there is one thing I should like to say in conclusion. As a background to it would say that I have had five years of industrial work in one of the Navy's plants on shore which was largely engaged in manufacture of a certain war weapon and in fact had a sort of monopoly on it at the time. It was a wholly enjoyable experience out of which I derived as much satisfaction in the way of things accomplished as I have had in any similar period of my life. In spite of the success which I claim I am fully convinced that manufacture of ships, their appurtenances and our war materials in general, in government plants should be confined to a relatively small proportion of the whole.

If we are to meet the tests which we hope will not come our way, but still may eventuate in the form of a grave national emergency, the best inventive research and engineering ability and the most efficient industry of the whole country is needed. The Navy does not admit that its fighting efficiency is less than those of other countries, but does not wish to surrender to any possible enemy any advantage in the quality of weapons which we may have to use. Whoever makes such weapons, wherever and however they are made, we want the very best that money can buy.

Admiral Hart was followed on the program by a distinguished, silvery-haired orator from the Middle West, Senator Guy Gillette, senior Senator from Iowa, and a member of the Naval Affairs Committee of the United States Senate. He speedily proved to the complete satisfaction of his audience, his right as a "Corn-belt Farmer" to talk to engineers and technicians about the Navy, and held his audience spell-bound with his clear argument, and forceful delivery. While much of his speech was extemporaneous, the substance of his remarks was as follows:

It is said that the great Italian tenor, Caruso, was possessed of such tremendous chest expansion that in the act of singing the expulsion of air was so great that when he attempted to make a phonographic record, it was necessary to discard scores of such records, because of the noise made by the air expulsion before a record could be secured worthy of preserving. A similar situation prevails with reference to many of us whose employment requires our speaking on many and varied occasions. It is our experience that many of the records we make consist principally of wind, and that only once in a great while is a speech made that has anything of value and is worthy of preservation.

When I was requested to speak before this assembly, I was duly appreciative of the honor accorded me, but since I have had an opportunity to glance over the long list of members and guests here present, my appreciation, while deeper still, is now tempered with trepidation. I suddenly gained a perspective of myself, a farmer and political representative of the Corn Belt, attempting to address a group of engineers, scientists and designers of marine machinery and accessories, apparently representing the most highly trained technicians of the industrial East. Although I come from a State about as far removed from the nation's shore lines as is possible for a State to be, yet may I digress for a moment to call attention to a part of the contribution of the State of Iowa to the United Sates Navy in partial condonation of my temerity in appearing here tonight. At the present time, two of the highest officers in our Navy are Iowans born—Admiral William D. Leahy, Chief of Naval Operations, and Admiral Harry E. Yarnell, Commander in Chief of the Asiatic Fleet. There are also on the list of active

Admirals today two gentlemen of exceptional merit, Admiral Arthur St. Clair Smith, Commandant of the Mare Island Navy Yard, and Admiral George J. Meyers, Commander of the Special Service Squadron. May I also, with considerable pride, call attention to the important role that other Iowans have taken in Navy annals. Admiral John G. Walker was the most powerful officer in the Navy for several years during the nineties. Admiral George C. Remey was Commander in Chief in the Far East during the critical times of nineteen hundred. Admiral Frank F. Fletcher was as prominent and as fine an officer as the Navy possessed in the time of the World War. Yet outside the official personnel, it is with considerable pride that I can state to you that on the thirtieth day of last June, the State of Iowa had 3,438 men in the United States Navy, more than any other State in the Union, regardless of population, with the exception of four. I hope this brief statement will partially excuse my acceptance of the invitation to speak to you tonight.

Individual progress is not measured by years, but by accomplishment. Some men live more in a few months' time than others in a full life period. A Beethoven may pass away in his early thirties and leave as a legacy to humanity musical compositions to thrill and inspire, and another may live a century and contribute absolutely nothing. A Nazarene, scarcely past his thirtieth birthday, may influence the destinies of hundreds of millions of people, and another, living far beyond the allotted span of life, exert no influence whatever, even in the lives of his closest neighbors. "We live in deeds, not year; in thoughts, not breaths; in feelings, not in figures on a dial. We should count time by heart throbs. He lives most who thinks most."

As with individuals, so it is with nations, and so it is with civilization. We have lived more and accomplished more for the human race and its material and moral betterment in the last one hundred years than in the entire two thousand years of the Christian era. We have done more for humanity since the turn of this century than during the entire five hundred years that we called the Dark Ages of the medieval period. The history of the growth of civilization is a history of the growth of the facilities of communication. Scientists inform us that in some of the caves in the Balkan region,

there are layers of debris and deposit more than forty feet in depth, from human occupants of these caves, and covering hundreds and hundreds of years of time, with no change whatever in the character of the deposits as to implements and evidences of the development of the arts and crafts until the period when the cave dwellers came into commercial contact with nations across the Mediterranean. Look back over written history and read the record! No nation ever took its place as a people of importance in the pages of history unless it was a nation whose chief interest and concern was the development of its commerce with other peoples, by extending its trade and transportation facilities and, together with this, the means of protecting that trade and those communications. Call the roll of these nations: Phoenicia, Greece, Carthage, Rome, Venice, Spain, The Netherlands, England. Without exception, each took its place and left its mark on the world and its history because of its development of maritime commerce and its efforts toward extending the lines of foreign trade. There is not an exception to the rule. Turn to our own history! It was not until the sea captains of New England and our other coast sections developed the clipper ships and with these plowed the sea lanes of the world's trade that the first steps were taken toward amalgamating the isolated American colonies into the beginnings of a nation. Realize, if you please, that for more than two hundred years after the colonization of this country, our forefathers had not penetrated more than eighty miles away from the coast, but that after the development of steam engineering in 1836, and within seventy-five years, the length and breadth of the United States had been made the subject of the most stupendous development the world has ever witnessed. Please consider further that with the development of electrical power in the last quarter of the nineteenth century, the foundation was laid for the astounding material national progress that received its further impetus with the turn of the century in the development of the internal combustion engine and the use of our oil resources as motive power which, along with the conquering of the air lines, brought the whole world into close relationship as to trade and progress, and has made possible not only for our nation, but for most of the people of the world a standard of living for the poorest that carries with it facilities and conveniences

that could not be purchased by the most opulent in the days of slow communication. Although the development of these engineering fields made us less than wholly reliant upon the high seas and the waterways for transportation, yet they have brought the portions of the world into such close communication and interdependence that we are commercially closer to Asia today than the people of Virginia were to the people of Massachusetts at the time of the independence of America.

My discussion of these developments is for the purpose of calling to our mind that although geographically we of the Middle West are more than a thousand miles from salt water, yet our future, as well as that of the whole nation, is entirely bound up in the development and protection of foreign trade for the agricultural and industrial products of our country.

Then there is another point. One might thoughtlessly assume that shipbuilding is primarily the function of shipbuilders, and that for sea-going ships, such activities might be confined to the salt-water coast line. Of course, this is true as to the actual assembly of ships, but the steel and machinery and the thousands of miscellaneous items of equipment and supplies to fit out modern naval vessels are drawn from almost every industry active in the country, including a great many located in my particular section, and it would appear then that modern shipbuilding, in a broad sense, for the Navy or the Merchant Marine is a nation-wide and not a localized industry, and the nation's money spent for it goes, in a large measure, back into the channels of trade and eventually reaches, in part, the pockets of the Corn Belt farmers who furnish a large portion of the food supply for human consumption by the industrial workers.

It is regrettable that there is a certain mistrust on the part of the general public, of the professional military and naval personnel. This is owing, in part, I am sure, to a lack of thought and consideration of the underlying facts on the part of those of us in the civilian channels, and our lack of familiarity and information on military and naval matters. But some of the fault can be justly charged, I am also convinced, to the lack of interest shown by some professional officers toward matters of public and civilian concern, and I trust you will forgive me if I say that there is but one letter,

the letter N, which differentiates the *uniformed* expert from the *uninformed* expert.

Our thousands of miles of sea coast and our continued interest in and dependence on foreign trade demand a powerful Navy, and our national economic interests demand a reasonable and dependable Merchant Marine. It is a truism that the Navy is the first line of our national defense, and it should be maintained at sufficient strength and efficiently enough manned and trained to accomplish this mission, regardless of the trend of our political life. To supply the necessary information as to what is necessary to accomplish this mission is the duty of our naval specialists. Even the casual observer cannot escape the conviction that a " feast or a famine " policy in naval building is not conducive to efficient or economical production of the best in fighting ships. A carefully thought out program of naval shipbuilding, conscientiously carried on, is infinitely superior to periods of intensive shipbuilding activity, alternating with long intervals of idleness in our shipyards. This is an age of the most intensive specialization and navies and naval armaments have now a wide and constantly changing field of specialized development. We must not permit our Navy to lag behind in applying to our naval defenses the best the country's scientists and engineers have to offer. In brief, we as a nation, cannot afford to indulge in long " naval holidays."

May I, in closing, refer to a matter of the deepest concern. We are living through one of the greatest crises of the world's history. We speak of the possibility of being drawn into a foreign war. We proclaim peace for America, and a position of neutrality. Our people wonder if we are to be drawn into the Spanish civil conflict. We are already in that conflict, and we are inextricably involved in the great contest that is embroiling the eastern hemisphere. It is not a civil war, with national limitations. It is not even a contest between nations. It is a contest being waged to the death between two schools of political philosophy. It has its reverberations in our labor contests and our political struggles on Capitol Hill. It is a contest between one school of political thought which maintains that all resources are for the benefit of the whole people and must be administered by socialized government and distributed on the basis of contribution; and the other school, which maintains

the right of private ownership of property to the point where the control is absolute and that private control of property must be maintained, regardless of the consequences to general society. This latter school holds that representative government as a means of effecting these ends has outlived its usefulness and must pass from the stage of political activity. This school finds its expression politically in such dictatorships as now exist in Europe. We belong to neither school. If this is civil war in Europe, it's civil war on an international scale, front to front. We still maintain the right of private property and that it can be secured under a form of government where we recognize no human law excepting that promulgated by representatives of our own choosing, and that, while recognizing the right to control property, we insist that control must be exercised in the public interests and not for private exploitation.

Whatever the outcome, the whole future of civilization depends upon the result of this struggle, and it seems to me definitely no time for this country of ours to neglect in any way its naval preparedness. I, for one, as a United States Senator, representing a midwestern State, will feel more optimistic as to the outcome, and can close my eyes at night with greater assurance of safety for my country and its future, if I know we have a modern, efficient, watchful and adequate fighting Navy, not only patrolling our coast line, but supporting our international interests, and our all-important lanes of commerce and trade.

The last speaker on the program was Mr. Homer L. Ferguson, the President of the Newport News Shipbuilding and Dry Dock Corporation, Newport News, Virginia. Over many years now, gatherings at industrial, technical, and scientific meetings in all parts of the country have waited expectantly to hear what this distinguished and respected captain of shipbuilding industry might have to offer them in the way of sound criticism, advice, and hope. He more than lived up to expectations in his address. While he spoke quite extemporaneously, and it is not possible to quote his words exactly, he held his audience with a message buoyant with the pride of accomplishment. He pointed out the great advances which have been made in power and speed with reduced displacement factors over thirty years of Naval shipbuilding in which he

has actively participated. And he noted that these advances had often been made in the face of almost insurmountable obstacles of legal and political restriction. He asked for more freedom today for the shipbuilders, and their sub-contractors, than is allowed by existing laws, and presaged an even greater measure of accomplishment for the future. He concluded his speech on a note of hope, and cooperativeness, which brought the evening's entertainment to a happy and satisfactory close. Some of the guests went home.

The Society cannot but be proud that its aims and interests are strong enough to bring together such a large and representative gathering—such a truly representative cross-section of the Nation's industry, and it looks forward to assembling an equally representative gathering to celebrate the Fiftieth Anniversary of its founding next year.

Remember, 1888-1938.

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THE TREND OF NAVAL CONSTRUCTION.

This article, extracted from the Journal of the Royal United Service Institution, London, England, quarterly issue of February, 1937, and prepared by the editor of that Journal assisted by Mr. Maurice Prendergast, is the result of a study of the current edition of Jane's Fighting Ships, (1936 Edition). It is presented in the hope that the brief analysis will interest many people in this country who have not grasped the idea of the energy and speed with which practically all nations of the world are strengthening their naval armament—an unfortunate race, but one in which we are forced to hold our own.

With the close of 1936, the restrictions on warship construction imposed by the Washington Treaty of 1922 and by the London Naval Treaty of 1930, lapsed. Today the Powers are all free to build as many ships of any class as they like. The verbose, but anæmic, London Naval Treaty of 1936 only imposes certain qualitative limitations on the fleets of Britain, the United States, and France, although it is hoped that, one by one, other nations will in due course come within its fold. In these circumstances, the time is ripe to take stock of the trend of naval construction abroad and to consider how far it should influence that rebuilding of our Navy on which we are now free to embark. In this task we shall have the invaluable assistance of the new edition of "Jane's Fighting Ships."*

BATTLESHIPS.

In spite of the extravagant arguments of those air enthusiasts whose imagination outstrips their intelligence, the battleship, as a type, remains the basis of sea security and continues to be recognized as such by all the principal naval Powers. But this does not mean that battleship design is taking no account of new forms of warfare: just as the introduction of shell fire led

* "Jane's Fighting Ships," 1936. (Sampson Low, Marston & Co.). Edited by F. E. McMurtrie, A.I.N.A. £2 2s. 0d.

to side armor and the development of the torpedo to an anti-torpedo craft armament and to "bulges," so the increasing range of the gun with the steeper angle of descent and greater penetrative capabilities of the shell—even more than the advent of the aeroplane bomb, have called for heavier deck armor. The danger of attacks by aircraft is being met, as was that of attacks by torpedo craft, by a suitable gun armament with its appropriate fire control, and by the requisite protection to the hull. Moreover, the battleship, like every other vehicle, ashore, afloat, or in the air, is moving with the times in the matter of increasing speed.

Until 1st January, 1937, Britain, the United States, and Japan were prohibited from laying down new capital ships, and the best they could do was to tinker with their old ones in an endeavor to modernize them—an expensive and not very satisfactory process. France and Italy not having made full use of their tonnage quota, were free to lay down new vessels; this the former felt impelled to do on the appearance of the three German "pocket" battleships. These vessels were legitimate replacements under the Versailles Treaty of the superannuated *Preussen, Lothringen,* and *Braunschweig;* but the combination of an armament of six 11-inch guns with a speed of 26 knots upset the balance of values of all existing capital ships, except our own and possibly Japan's battle cruisers, for the simple reason that the German ships were too fast for any battleship to catch and too powerful for anything less than a battle cruiser to kill. The French reply to them was the *Dunkerque* and *Strasbourg**—ships of more than double the displacement of the *Deutschlands,* armed with eight 13-inch guns, having a speed of 30 knots and much thicker armor.

The next move was made by Italy, who, in October, 1934, laid down two 35,000-ton battleships, the *Littorio* and *Vittorio Veneto,* with an armament of nine 15-inch guns and a designed speed reputed to be in the neighborhood of 34 knots. Full details are as yet lacking, but it seems obvious that these vessels will have to economize somewhat in armor if they are to be so well equipped in guns and engines.

In the autumn of last year Germany burst her bonds and laid down two 26,000-ton battleships, named the *Scharnhorst* and *Gneisenau* after von Spee's ships of Coronel and Falklands fame. These appear to be intended as the answer to the French *Dunkerques.* Their design seems to indicate that Germany is adhering to a principle which was justified by her experience in the late war—she is content to arm her ships with guns of a less caliber in order that they may have better protection than those of their contemporaries. So we find the main armament of the *Scharnhorsts* is nine 11-inch as compared with the eight 13-inch of the French ships. In practice this disparity may not mean any inferiority in fire effect because, within limits, it is the weight of metal per minute which *hits* an enemy which counts, and the lighter gun may make up in rapidity of fire what it lacks in weight of the individual shell. Below a certain size, of course, penetration starts to deteriorate.

The Franco-German competition has not stopped there: in 1936 Germany laid down a 35,000-ton battleship, which it is believed will carry a main armament of 14-inch guns and have a speed of 30 knots, and a sister ship is to follow in 1937. France is replying with the *Richelieu* and *Jean Bart,* also of the maximum Treaty displacement, to be armed with eight 15-inch guns and having a designed speed of 33 knots.

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* The *Dunkerque* has run her trials; the *Strasbourg* is not due for completion until 1938.

In the light of these developments, details of our *King George V* and *Prince of Wales,* laid down on 1st January, will be awaited with much interest. All that has been made public about them as yet is that they will be 35,000-ton ships and carry an armament of 14-inch guns. It is known that very special attention has been paid by the Admiralty lately to the whole problem of protection against bomb and torpedo attacks; our new battleships, therefore, are not likely to be deficient in armor or water-tight subdivision, while the very considerable reduction in the caliber of the main armament, as compared with the *Nelson's* and *Rodney's* 16-inch, gives grounds for hope that they will not be lacking in speed.

It is remarkable that the United States naval authorities should be content with a speed of only 26 to 27 knots in the ships which are to be laid down in June of this year. Mr. Swanson's argument that they are building "battleships, not battle cruisers," seems to ignore the fact that a ship which is inferior in speed can never hope to be able to catch, hold, and kill her rival or prevent her preying on weaker craft: for example, there will be no American ships which could catch, hold, and kill any of the latest German battleships. As regards armament, the U. S. Navy Department is avowedly waiting to see what the Japanese will do. Unless the latter subscribe, in effect at any rate, to the Three Party Treaty and limit the armament of their new battleships to 14-inch caliber, the American ships will mount 16-inch guns. It is possible, of course, that if the lighter armament is adhered to, the ships will be faster than is at present projected.

Another feature of the capital ship of today is the addition of aircraft to her ever-increasing equipment. The majority of the battleships of all navies have had, or are having, one or more catapults installed for launching float-planes. The four latest French ships are being provided with four aircraft each; the older *Lorraine* has had a center twin-13.4-inch turret removed and replaced by a catapult. All the German battleships of the *Deutschland* class and later have been or are being given a catapult and two aircraft each. Italy's new ships are to have one or more catapults and four aircraft; the older battleships *Cavour* and *Cesare* have had their center twin 12-inch turret replaced by two catapults and four aircraft. (Incidentally these ships have been rearmed, lengthened by 34 feet and their speed increased from 22 to 27 knots). Japan has been slow to introduce aircraft into her capital ships, but catapults are being installed gradually.

Aircraft are rapidly making their appearance in our own battleships and battle cruisers, and in the course of their recent reconstruction the *Malaya, Warspite,* and *Repulse* have been given hangars to house four aircraft, and equipped with catapults and a crane. This is not an indication of any movement towards a combined battleship and aircraft carrier—a rather visionary design, and there is no indication that any nation intends to build a class of vessel which, in practice, could only be a second-rate fighting ship and an inefficient carrier.

A new development is the tendency to eliminate the torpedo armament from capital ships. In the late war it certainly did not prove its utility or justify the risk attached to the large under-water compartments required for submerged tubes. The United States, France, Germany, and Italy are omitting torpedo tubes in all their latest battleships. As they have recently been removed from three of our *Queen Elizabeth* class, it would seem that we are following suit.

The disposition of the main armament of capital ships is governed to a large extent by considerations of weight, and by grouping the turrets together, as in our *Nelson* class and the French *Dunkerque,* appreciable economy in the armoring of vitals is obtained. But the question is one which also has a distinct bearing on the relations between tactics and fire effect.

For instance, the *Nelsons* and *Dunkerques*, with all their guns bearing ahead, are well suited for chasing, but not for being chased. At the other end of the scale, if the forecast in "Jane's Fighting Ships" is correct, there will be the new Italian ships with six 15-inch guns bearing astern, and only three ahead—obviously better equipped for fighting a retreating action. The German *Scharnhorsts* seem to aim at the happy mean by giving preference to ahead fire (six 11-inch) without neglecting stern fire (three 11-inch). As all modern turrets have wide arcs of bearing, there is not much to choose between any of these dispositions for a more or less broadside action; but from a tactical point of view there is much to be said for the well-balanced arrangement of our *Queen Elizabeths* and *Royal Sovereigns*, with their two turrets forward and two aft, and, as ships, they are certainly more pleasing to the eye than the later *Nelsons*.

AIRCRAFT CARRIERS.

Apart from the fact that the new Treaty reduces the displacement of carriers in three navies from 27,000 to 23,000 tons, there seems to be a growing preference for a smaller type. The huge *Lexington* and *Saratoga* (33,000 tons), the *Kaga* and *Akagi* (26,900 tons), and even our *Eagle* (22,600 tons), *Furious*, *Courageous* and *Glorious* (22,500 tons) are recognized as being unduly large and vulnerable baskets with an over-concentration of eggs. The United States *Enterprise* and *Yorktown* (19,900 tons), *Wasp* (14,700 tons), and recently completed *Ranger* (14,500 tons); the Japanese *Soryu* and *Hiryu* (10,500 tons) and *Ryujo* (7100 tons); and the fact that our *Ark Royal* (22,000 tons) is to have smaller successors in the *Illustrious* and *Victorious*, all show that the trend is towards a lighter and more economical type. It must be realized, however, that with the growing number of aircraft required for fleet work, a reduction in the size and capacity of the individual carrier will mean that a greater number of these ships will be required.

The gun armaments of carriers also show a general reduction from the 8-inch caliber of the early American and Japanese ships, and the 6-inch of our *Eagle* to purely A.A. armaments such as the 5-inch guns in the *Ranger* and *Ryujo* and their successors, and the 4.7-inch A.A. in our *Ark Royal*. This implies that, in future, carriers will only be expected to protect themselves against aircraft and, perhaps, torpedo attacks; and that they will be shielded by the battle fleet, cruisers and escorting destroyers from encounters with more heavily armed vessels.

CRUISERS.

The London Treaty of 1936 decrees that there shall be no more 8-inch cruisers. But even those nations who have not subscribed to it, show no desire to perpetuate the type. Such a heavy armament, especially on a limit of 10,000 tons, meant an undue surrender of speed or protection or both. To a great extent it has been American insistence which perpetuated the type ever since the Washington Treaty; but Admiral Standley has at last admitted that it has its defects and that a smaller class has its merits. So far, however, the U. S. Navy Department, while reducing the armament to 6-inch, has maintained a 10,000-ton displacement for their new *Brooklyn* class. These are clearly intended to be the answer to the Japanese *Mogami* type; the latter nominally displace only 8,500 tons, but their fifteen 6.1-inch, as compared with the fifteen 6-inch of the American ships and an exactly similar A.A. armament of eight 5-inch and speed of 33 knots, would seem to necessitate more tonnage than is admitted.

Italian cruisers are notoriously suspect both as regards the conditions under which they obtain their phenomenal speeds on trials and their professed tonnage: the *Trento* and *Trieste,* contemporaries of our *London* class, carry the same main armament (eight 8-inch), a much heavier A.A. armament (sixteen 3.9-inch as against our four 4-inch), and appreciably more side armor, yet they have achieved an average speed of 36.6 and 35.6 knots respectively, as compared with our ships' average of about 32.5 knots. The later *Bolzano,* with slightly lighter armor, is credited with an average speed of 38 knots on an eight-hours trial. The designed horsepower of the Italian cruisers' engines is 150,000, as compared with the 90,000 to 120,000 of the French, 107,000 of the American, 100,000 of the Japanese and 80,000 of the British ships of a similar class. How is it done on the same displacement?

The American notion that nothing less than a 10,000-ton, 8-inch-gun cruiser could be counted on to deal with a multiple 6-inch gun armed merchant liner is now exploded, and the 8000-ton, 6.1-inch gun vessel of the new Treaty is probably only the "sealed pattern" of a fashion which will be pretty generally followed. Germany had to demonstrate her independence by laying down three 10,000-ton, 8-inch gun ships; but these will probably be the last of the type.

France is completing six useful little ships of the *La Galissonnière* class, displacing 7600 tons (9120 full load), carrying nine 6-inch and eight 3.5-inch A.A. guns and having a designed speed of about 32 knots. These vessels are interesting, too, because they have a hangar capable of housing four aircraft, and a catapult and are built with a square stern adapted for towing a landing-on (Hein) mat.

Italy is completing her two *Garibaldi* class of 7874 tons (9000 tons full load), carrying ten 6-inch and eight 3.9-inch A.A. guns, four aircraft with two catapults, and having a designed speed of 35 knots. Again, how does she do it on the displacement?

In view of the comparatively large cruisers still being laid down by foreign Powers, we have been compelled to build the ten ships of the *Southampton* class, displacing 9000 tons and armed with twelve 6-inch and eight 4-inch A.A. guns. Exact details of their armor have not yet been made public; but they will be better protected than the *Londons,* while their speed will be little, if at all, inferior to them. The 1936 Estimates also made provision for five smaller 5000-ton cruisers—*Dido* class—which will also carry 6-inch guns.

Aircraft are now being universally included as part of cruisers' equipment, and in our *Southampton* class hangars are provided just abaft the foremost funnel. It is interesting to recall that the *Dragon, Dauntless, Carlisle,* and *Capetown* all had hangars during the latter part of the War, although they were subsequently removed when it was our policy that aircraft should only be used from carriers.

All the torpedo tubes have been removed from the later American 8-inch cruisers, and none are being mounted in the new 10,000-ton, 6-inch-gun ships. On the other hand, while the earliest Italian cruisers of this type (*Zara* class) have no torpedoes, the later ships follow the fashion of other nations, including ourselves, in mounting above-water tubes. Nevertheless, there seems to be a general inclination towards eliminating the torpedo armament from heavier ships, and relegating it to the lighter and faster craft.

LEADERS AND DESTROYERS.

While the tendency is to reduce the size and armament of larger types of warships, the flotilla leader and destroyer have steadily increased in both, until to-day many of the former are virtually small cruisers, while the destroyer now aims at being the antidote to her own kind, instead of to the practically defunct torpedo-boat.

Amongst vessels officially classified as "leaders" we find the French *Mogador* class, which, fully loaded, will displace over 3000 tons, and which will carry eight 5.5-inch and four 37-millimeter A.A. guns and nine 21.7-inch tubes; the Polish *Grom* class (built in England), of 2200 tons, armed with seven 4.7-inch and four 3-inch A.A. guns, and six 21-inch tubes; the American *Porter* class, of 1850 tons, with eight 5-inch (dual purpose) guns and eight 21-inch tubes; and the Japanese *Hubuki* class, of the same displacement, armed with six 5.1-inch and two A.A. guns, and nine 21-inch tubes. Speed, as might be expected, rises more or less with tonnage from the 34 knots of the Japanese vessels to the 38 knots, or more, of the French.

Our sixteen *Tribals,* laid down in 1936, are doubtless intended to be contemporaries of those foreign leaders. On their 1850 tons displacement they are to carry seven 4.7-inch guns and eight 21-inch torpedo tubes. The designed speed has not yet been announced.

The destroyer, from being a craft of 600-700 tons, has grown to double that displacement. Notable new types are the American *Mahan* class, which on 1395 tons carry five 5-inch (dual purpose) guns and eight 21-inch torpedoes,* and have a designed speed of 36.5 knots; the Japanese *Shigure* class, of 1368 tons displacement with five 5-inch guns, eight tubes, and 34 knots; the French *Le Hardi* class, of 1772 tons, mounting six 5.1-inch guns and six 21.7-inch tubes, and having a designed speed of at least 37 knots; and the Italian *Oriani* type of 1498 tons (about 1850 fully loaded), carrying four 4.7-inch and four 37-millimeter A.A. guns and six 21-inch tubes, with a designed speed of 39 knots.

British destroyers of the 1935 and 1936 Programmes—eight *Javelins* and eight *Intrepids*—will displace the normal 1350 tons, carry four 4.7-inch guns and eight 21-inch tubes, and have a designed speed of 35.5 knots.

A review of these developments tends to confirm the impression that, for some time now, an attempt has been made to combine too many functions—and consequently excessive armaments and equipment—in one type of vessel. It would seem to be more logical and more economical to produce a class with a powerful gun armament and reasonably high speed to act as the battle fleet's satellites and to counter attacks by torpedo-craft (destroyers and submarines) and low-flying aircraft; and another, smaller type, armed primarily with torpedo tubes and having the highest possible speed, whose functions would be to deliver torpedo attacks—especially at night, and to carry out night reconnaissance.

SUBMARINES.

Since the War, the submarine has grown in size, endurance, habitability, surface speed (where required), and armament. The 1936 Treaty has renewed the 2000 tons and 5.1-inch gun restrictions of the 1930 Agreement, and except for a few freaks like the French *Surcouf,* the American *Nautilus, Narwhal,* and *Argonaut,* and our *X.1* (now on the sale list), there has been

* It is believed that later vessels of this class will mount twelve tubes.

no tendency to exceed this size. Japan has built or is building eight 1900-ton craft, known as the *I* or "fleet" class, each of which carry six 21-inch tubes; the first four and the last two mount two 5.5-inch guns. *I.5* and *I.6* carry one 5-inch; as *I.5* has a tubular hangar abaft the conning tower with a small seaplane instead of the second gun, it seems probable that *I.6* will be similarly equipped. The latest American submarines include twelve of 1450 tons, whose armament is six 21-inch tubes and a 3-inch A.A. gun. France and Italy are building under-water craft of some 1350 tons.

After our *Thames* and *Porpoise* classes, of about 1800 tons and 1500 tons respectively, we are returning to a smaller type in the 1100-ton *Triton* class.

Most foreign nations are also building small, coastal type, submarines. Germany, who has had more experience of the offensive use of submarines than any other nation, has started to rebuild her flotillas with quite small craft, probably because they can be produced quickly. *U.1* to *U.24* displace only 250 tons; *U.25* and *U.26*, 712 tons; and *U.28 to U.40*, 500 tons; but from *U.25* onwards they all carry six 21-inch tubes.

A surface speed of 20 knots is not phenomenal for modern submarines, and the *Thames* and her two sisters attained over 22 knots on trials. The normal surface speed of the modern submarine is in the neighborhood of 17 knots, and the submerged speed 9 to 10 knots.

MISCELLANEOUS.

Amongst other noticeable features in modern naval construction is the tendency to economize weight by welding, by the use of very light plating where permissible, and the adoption of large and few boilers rather than small and many; the introduction of higher pressures and superheated steam; and, of course, the universal use of oil fuel.

Another weight-saving device is the multiple-gun mounting: this is no longer confined to the turret armaments of battleships, and the triple mounting—even a triple 8-inch, has found its way into cruisers; and the twin—5.1-inch and downwards, into destroyers.

Considerations of weight, space, fire-control, ammunition supply, and reduction of personnel all point to the necessity for replacing the conglomeration of auxiliary armaments by a "general purpose" one, suitable for engaging aircraft, torpedo craft, or submarines. There are indications, especially in the United States navy, that this problem is on its way to being solved. Anti-torpedo craft guns have for some years been given an elevation of about 60 degrees; it should be well within the scope of our designers to produce a mounting which will provide for 90 degrees elevation, adequate depression, light handling, and rapid loading for guns up to 5 inches.

The very fast motor torpedo-boat of the C.M.B. type is generally popular, and our successes with it in the late war have commended it to many navies.

The most noticeable feature of all, however, is not so much any very striking novelty in the latest construction, but its growing volume. The round-table meetings at Geneva, the disarmament conferences, naval conversations, treaties, and pacts which have been the milestones in international relations since the War, have all promoted the most intensive comparisons of national armaments; and to-day there is scarcely a single government which is content or feels secure with what they have got. Unless a "formula can be found" which will put an end to all this international chatter and allow the ordinary citizen, no matter what his race or creed, to pursue his business in peace and without the alarms and excursions manufactured by his political leaders, "Jane's Fighting Ships" will grow into a very bulky volume in the years to come.

DEVELOPMENT OF THE TWO-STROKE OIL ENGINE.

This extract from a lecture recently delivered before the Spring Meeting of the Institution of Naval Architects of Great Britain by Mr. W. S. Burn has been drawn from the April, 1937, issue of the British Motor Ship. The lecture itself received a great deal of attention abroad, evidenced by numerous references to it in current German, French, and British periodicals. Recent developments here and abroad, make the article interesting at this time.

The earliest forms of oil engine operated on the four-stroke cycle, when two complete strokes were required for the exhausting from the cylinder of the burnt products and the replenishment of a fresh cylinder charge of air. The use of the working cylinder and parts for this purpose entails that they must work seriously under design capacity for half of their life, and of necessity results in a somewhat uneconomic utilization of material.

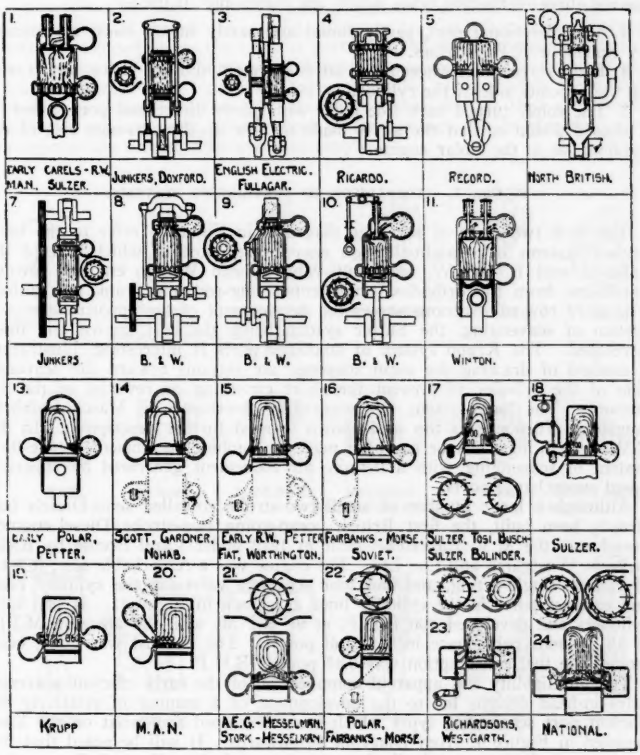

FIG. 1.—COMPARISON OF SCAVENGING SYSTEMS.

In the two-stroke cycle the exhausting air and air charging is concentrated into from 90-120 degrees at the end of the expansion and the beginning of the compression stroke. To accomplish this with efficiency and reliability has inspired an incredible amount of invention and experiment without precedent or equal in marine engineering.

Dealing first with the various methods adopted to scavenge the cylinder a diagrammatic review of the more interesting scavenging systems is given in Figure 1, which is largely self-explanatory. Broadly there are two basic systems, the uniflow and the double-flow.

The modern uniflow system comprises:—

1. The opposed piston, i.e., Junker, Doxford, Fullagar, N.B. sliding cylinder, the Ricardo sleeve-valve, and the duplex Record engines.
2. The valve-in-head types, such as the Winton, B. and W., and Harmonic Petter engines.

The double-flow scavenging system may today be classified into the following three distinctive types which are commonly in use:—

1. The directional port, partly radial and partly turned back, represented by Sulzer or R.W. engines.
2. Loop scavenging, wherein the air is directed onto the piston and travels up the opposite side of the cylinder.
3. The solely turned back side ports with partly directional ports aided by a shaped piston so that the air is made to flow up the scavenge side of the cylinder, as in the Polar engine.

FIGURE 1.—COMPARISON OF SCAVENGING SYSTEMS.

The first two rows of scavenge diagrams in Figure 1 refer to the best-known systems of straight-through scavenging, most of which, except the valve-in-head B. and W. and multi-valve-in-head Winton engines, involve variations from the orthodox single connecting-rod and crank mechanism. The third row of diagrams shows the development of the opposite side port system of scavenging, the Sulzer system being the best known and most developed. The Krupp system of auxiliary ports is interesting, illustrating a method of drawing the main scavenge air streams toward the scavenge side of the cylinder to prevent the short circuiting or reversal of the air streams. The loop system, so successfully developed by Maschinenfabrik Augsburg-Nürnberg, is too well known to need further description. In the R.W. system an endeavor has been made to combine an efficient double-flow system of scavenging with a definite air movement generated by superimposed supercharge ports.

Although a large number of small two-stroke so-called semi-Diesels had already been built, the first British ocean-going two-stroke Diesel-engined vessel was the M.V. *Eavestone*, built in 1912 under Carel license by Richardsons, Westgarth and Co., Ltd. The engine was a remarkable one; it was, of course, single-acting, and had four scavenge valves in the cylinder head and exhaust ports in the cylinder liner as shown in Figure 1. It had four cylinders and developed 800 B.H.P. at 90 R.P.M. with the amazing M.I.P. of 127 pounds per square inch at full power. The exhaust was good, even though the fuel consumption was 0.47 pounds B.H.P.

The unreliability and apparent complication of the early efficient scavenge valve-in-head designs led to the development of a number of relatively inefficient port scavenging types which have developed somewhat on the lines depicted in Figure 1, from Diagram 13 onwards. It will be noted that the unsymmetrical piston gradually became symmetrical on lines similar to that

employed in the Scott or Fairbanks-Morse designs, and almost simultaneously a directional port system was perfected, which was completely independent of the shape of either the piston top or cover bottom.

The commercial progress which has been made with the opposed-piston engine in this country as represented by the Doxford engine is too well known to need repetition. For reliability with efficiency it is in a recognized class by itself. In this case the fundamental correctness of the scavenging system, the compact spheroidal combustion chamber, and the precise fuel-injection system have outbalanced the defects arising from any increase in the number of running parts, and lately the adoption of welded steel for the entire main structure has enabled low weights per B.H.P. of about 175 pounds to be obtained.

A NEW SCAVENGING SYSTEM

In an endeavor to obtain the advantages of the opposed piston engine with a single piston, a completely new system of port scavenging, chiefly intended for high-speed medium-size single-acting engines, was devised some time ago by the author, as shown in Figure 1, Diagram 24. In this case the scavenge ports are situated above the exhaust ports, both of which completely encircle the liner so that a minimum axial height is required for the requisite port area. The scavenge air ports are valve controlled to open when the exhaust pressure has dropped below the scavenge pressure, but as they are situated above the exhaust ports, some degree of supercharge can be obtained, given an appropriate scavenge air-pressure supply.

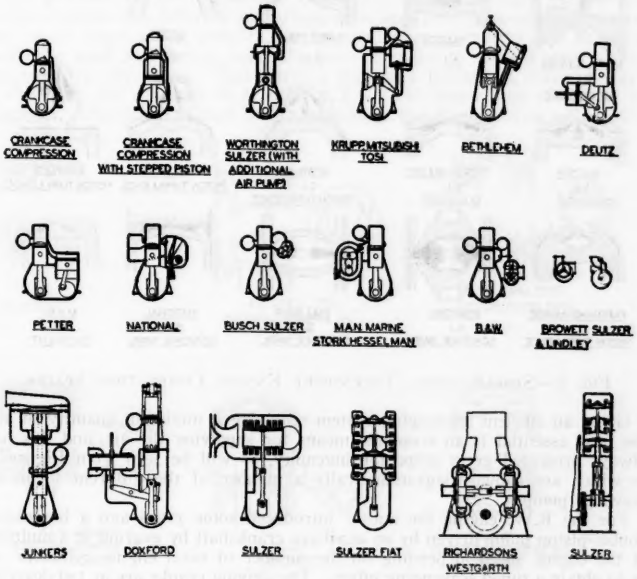

FIG. 3—VARIOUS TYPES OF SCAVENGING PUMPS.

The scavenge ports are inclined upward and tangentially so that the scavenge air streams describe helical paths, and are guided by the cylinder walls to the top of the cylinder, the width of the annular helicoid thus formed increasing as the cylinder head is approached. The upward air is reversed by the curved double converse cover bottom and forced down the center of the cylinder, the slightly conical piston top assisting the gas dispersal towards the exhaust port. The ring of scavenge air streams keeps the exhaust gases away from the lubricated surfaces, and has a surface cooling effect; at the same time the tangential swirl keeps the dense air to the outside, and generally has a stabilizing effect. The resultant shape between the cover bottom and piston top forms an efficient combustion chamber for a central fuel valve with approximately horizontal sprays, and an air movement with a strong horizontal air swirl, and a slight rotary movement in a vertical plane; this combustion space is shown in Figure 4.

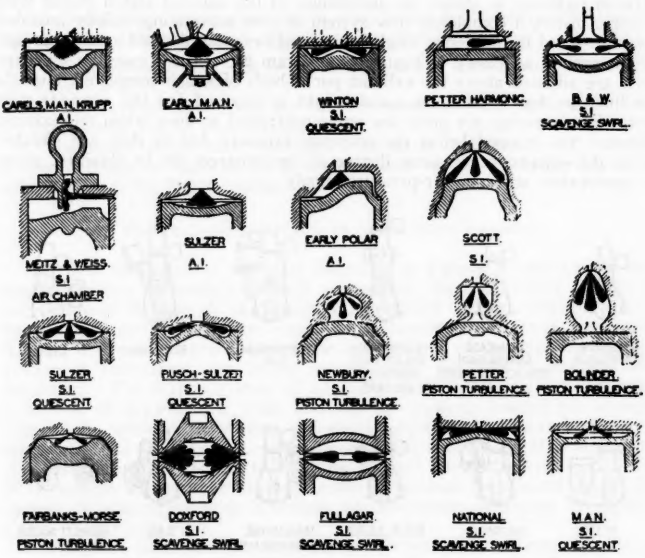

FIG. 4.—SINGLE-ACTING TWO-STROKE ENGINE COMBUSTION SPACES.

Given an efficient scavenging system requiring a minimum quantity of air, the next essential is an economic means for supplying the air, and this has always presented great scope for ingenuity, as will be seen from Figure 3, in which are shown diagrammatically a number of the different forms of scavenge pumps.

For the R.W. engine the author introduced some years ago a horizontal double-piston pump driven by an auxiliary crankshaft by gearing at a multiple of the engine speed, depending on the number of main engine cylinders, so as to obtain a timed scavenging effect. The driving cranks are at 180 degrees, so that a good dynamic balance is obtained. The valves are of the rotary

type driven by chains. Excellent indicator cards are obtained from this pump, and the maximum pressures are low for a given average pressure, which is usually 1.8 pounds-square inch.

For relatively high-speed engines the author has recently developed a refined timed scavenge system with a cam or eccentrically driven light alloy oscillating flap, which can be made to give the precise differential pressures required for both scavenging and supercharging at the correct periods to enable one set of parts and passages to be used. There is a separate pump for each cylinder, and one valve serves as suction, delivery, and supercharge valve, as shown in Figure 3.

It is surprising to note the widely varying designs of combustion chambers which have been used in the innumerable designs of two-stroke-cycle oil engines of the past. A limited review of these for single-acting engines is shown in Figure 4.

The original valve-in-head scavenging engines, such as the early Carels, Krupp, and M.A.N., had orthodox flat cylinder cover bottoms, and varying shapes of dished piston tops; as air injection was the order of the day, the shape was not critical. The shape, as in the Carels engine, Figure 4, probably was as good as any from a combustion point of view.

DOUBLE-ACTING COMBUSTION CHAMBERS.

Whilst the top cylinders of double-acting engines can be identical to single-acting practice, the presence of the piston rod has imposed definite limitations to the shape of the bottom chamber.

The problem has been tackled in two ways: One is to make the top and bottom combustions different and arrange the best possible combustion chamber, as in single-acting practice, at the top, when a central fuel valve is invariably used, and then to make the lower chamber to suit the sprays from two or more fuel valves. This latter is done in a number of different ways as shown by the solutions of M.A.N., A.E.G., and Sulzer, and illustrated in Figure 5. The other follows on the reasoning that, once having obtained a

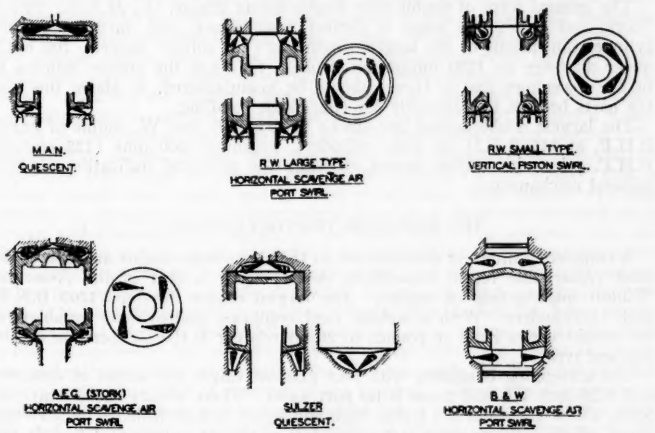

FIG. 5.—DOUBLE-ACTING TWO-STROKE ENGINE COMBUSTION SPACES.

good solution of chamber and fuel sprays for the bottom cylinder, the same system should be utilized for the top cylinder, and so have identical fuel valve and fuel-spraying conditions.

In the case of the R.W. engine the combustion conditions are very similar, and identical mean pressures are obtained. The power from the lower cylinder due to the area of the piston rod is 90 per cent of that of the top cylinder.

The author believes that the chief immediate future of the high-powered two-stroke engine will rest with the large double-acting type when direct propeller drive is desired; for powers below 2000 B.H.P. the single-acting engine is more nearly competitive. On the other hand, when the indirect geared or electric drive is considered, the really high-speed trunk piston type of single-acting engine seems to have great possibilities in the future. The type of engine envisaged by the author, and now being developed, is one with cylinders of about 12½ inches diameter, with an 18-inch stroke, and at 500 R.P.M. to develop about 250 B.H.P. per cylinder. Such an engine will have a considerable application, using different numbers of cylinders, with weights of about 50 pounds per B.H.P., including the gearing.

For powers of 2000-10000 B.H.P. in a single engine, the direct-drive slow-speed double-acting two-stroke can be built to weigh not more than 100-125 pounds per B.H.P., even with very substantial scantlings.

In large engines the experience of the author indicates that it is possible to obtain, by careful research of the air streams, quite as perfect evacuation of the exhaust products with scientifically designed directional ports as with any straight-through scavenging system. Swirling supercharge is then obtained at the expense of only a small valve and operating gear. If a comparison is made of the proportions of the stroke occupied by the exhausting and scavenging process of the R.W.-type engine with that of a large straight-through scavenging engine it will be found that the side scavenging exacts only a small loss of useful stroke to set against the much greater mechanical complication of the so-called uniflow types, the loss in expansion stroke being 19-20 per cent in both cases for exhaust, whilst the scavenge portion of the stroke amounts to 10-11 per cent in both cases.

The general form of double-flow double-acting engine, i.e., M.A.N., Sulzer, Stork, and R.W., has today a distinct resemblance, and, furthermore, the cylinder dimensions of the largest engines are all similar, namely, 700 millimeter diameter by 1200 millimeter stroke. This size the author believes to be the maximum that a Diesel should be manufactured, as above this size the parts become too unwieldy for convenient handling.

The largest double-acting two-stroke built is a B. and W. engine of 22,000 B.H.P. at 115 R.P.M. in eight cylinders, weighing 1200 tons (122 pounds-B.H.P.), but the author cannot envisage the practical utilization of such colossal mechanisms.

THE HIGH-SPEED TWO-STROKE ENGINE.

A completely different development to the above huge engine and one of the most remarkable recent two-stroke developments is that of the American Winton single-acting oil engine. The largest engine develops 1200 B.H.P. with 16 cylinders. With a welded steel crankcase and cylinder entablature, the weight varies from 16 pounds to 20 pounds per B.H.P., depending on the size and type.

The scavenging is uniflow with four exhaust valves 2¾ inches in diameter and 9/16-inch lift, and there is no port swirl. There are 24 radial scavenge ports, which are about 1½ inches high and about ½-inch wide. The scavenge pump, which delivers about 6000 cubic feet of air per minute at 4 pounds per square inch, consists of a single three-lobe helical Roots blower driven at 1500 R.P.M., from the forward end of the engine by a chain.

The weight of the piston and connecting-rod is only 87 pounds or 1.73 pounds per square inch of piston, which, even though the piston is aluminum alloy, is a very good figure. The gudgeon-pin has needle roller-type bearings, and the crankpin bearing has lead-base bearing metal.

The author feels that high-powered, multi-cylinder trunk engines of this style, with perhaps larger and fewer cylinders than the above, will ultimately become the dominant type. The most important point is to have a thoroughly well-developed standard size of cylinder, perfected to give established technical excellence, and then to manufacture the resultant engine on a mass-production basis.

TELEVISION.

This is an abstract of a lecture delivered on the 15th of December, 1936, in Glasgow, Scotland, by Professor G. W. O. Howe, D.Sc., and originally published in the Transactions of the Institution of Engineers and Shipbuilders in Scotland, Vol. 80, Part 4, dated February, 1937. As our British brethren have progressed in this art somewhat beyond us, having actually progressed out of the laboratory and into service, this readable description of their progress thus far is of interest.

The object of this lecture is to explain the principles of television so that the reasons for the slow development may be understood. The history of the practical applications of electricity in the early part of last century shows that the idea of using the electric current for transmitting pictures is a very old one. As is well known, the transmission of speech and music made enormous strides after the great invention of Graham Bell in 1876, and it is natural to ask why the transmission of moving pictures has progressed so much more slowly. When an orchestra is broadcasting it makes no difference to the enjoyment of the listener if the first and second violins, or even the drums and oboes, change places during the performance, because the microphone picks up the resultant total sound at any moment and transmits a current corresponding to that total sound. With a picture, however, a new element enters, namely, the necessity of reproducing every part in correct space relationship to every other part. The first operation in television is called "scanning the picture," that is, looking at every element into which the picture may be divided in rapid succession, and varying the current transmitted in accordance with variations of light and shade in the picture. To make things simple, assume that the picture is a draughtboard and that an apparatus resembling an electric eye can be focused on one square, that it covers exactly one square, and is blind to all else. The electric eye will transmit a signal to the receiver where there is a lamp also focused on a screen and illuminating a square of the same size. The scanning eye and the reproducing lamp must be made to move together in exact synchronism and always be focused on corresponding spots on the picture and screen. When the electric eye passes from a white square to a black one, its illumination falls and it transmits a reduced current that causes the lamp at the receiving end to give a reduced illumination. As the electric eye moves along a row of squares so the reproducing lamp sweeps along the screen, but varying in brightness, thus reproducing the alternate dark and light patches, but not with the sharpness of contrast of the original. When the electric eye is half on a black square and half on a white one it cannot transmit this complicated intelligence, but merely transmits a signal corresponding to the average illumination, thus rounding off and obliterating all the sharp detail of the original.

Having scanned one line, the eye and lamp must snap rapidly back and scan the next line, and so on until the whole picture has been scanned and reproduced bit by bit. To give the picture received a steady appearance with not too much flicker, this whole process must be repeated about 25 times per second. Now arises a very important question, namely: Into how many squares, or lines, should the picture be divided? If the electric eye covers a large area the picture will be covered in few lines, but there will be no detail—this is known as low definition. If the electric eye covers an area as large as a person's face in the picture, then it transmits a plain patch of average intensity but with no trace of eyes, nose or mouth. Such crude results are obtained if the picture of, say, 3 by 4 inches is divided into 30 by 40 squares. To obtain high definition the picture would have to be divided into, say, 300 by 400 squares. Assuming the picture to be a draughtboard, the effect of the scanning will be to transmit a current which increases and decreases, two squares corresponding to a complete cycle. A picture of 1200 squares transmitted 12·5 times per second, which corresponds roughly to the experimental low definition system employed by the B.B.C. for some years, would necessitate the transmission of a signal having a frequency of 7500 cycles per second, whereas with a picture of 80,000 squares transmitted 25 times per second the frequency would be a million. We must now consider why the transmission of the former was permissible on an ordinary broadcasting wavelength, whereas the latter can only be carried out on a very short wavelength.

If two men are walking side by side but taking a different number of steps per minute they will keep on getting into step and then out of step. If an organist plays two notes a semitone apart, the resultant discordant noise appears to be pulsating due to the air vibrations being sometimes in conjunction and sometimes in opposition. When a wireless station is transmitting, and there is a momentary silence, it is still sending out its waves, and if the wavelength is 300 meters the frequency is a million. Let it be assumed for simplicity that the music commences with a simple pure note having a pitch of 1000; the effect of this is to make the intensity of the wave sent out vary up and down at the rate of 1000 times per second. This gives a wave of radio frequency 10^6 modulated at an audio frequency of 1000. This was the kind of effect obtained by the organist by simply playing two steady notes of slightly different frequency; conversely, the signal sent out by the wireless transmitter may be analyzed into three steady waves having frequencies of 10^6, $10^6 + 1000$ and $10^6 - 1000$. This signal will affect receivers tuned to any of these frequencies. When an orchestra is playing it produces air vibrations covering all frequencies up to about 10,000, and the effect of this on the transmitted wave is equivalent to the sending out of every frequency between 990,000 and 1,010,000, and to get a good reception of the music a receiver must be capable of receiving all waves in this range. This shows why different transmitters must work at well-spaced frequencies unless they are very distant. It also explains why when listening to the long-wave Berlin station, the listener hears frequent hissing noises which occur whenever the speaker on the Droitwich station says a word containing the letter "s." The sound of this letter contains some very high frequencies, which spread the wave band, so that it splashes over into the range of the receiver tuned to the Berlin station.

Low definition television only required the transmission of modulating frequencies up to about 7500, that is, of the same order as ordinary broadcasting, whereas it has been shown that high definition television necessitates a modulating frequency of about a million, which would cover the whole broadcast band and make any other transmitter impossible. By decreasing the length of the carrier wave, that is, the basic wave that is to be modulated,

to 6 meters, its frequency becomes 50 million. When this is modulated at a frequency of a million, the range covered is from 49 to 51 million, that is, about 2 per cent on either side of the carrier frequency. Two per cent on either side of a wavelength of 6 meters occupies a very small part of the available spectrum.

A draughtboard has been assumed for the sake of simplicity and regularity; in an actual picture the variations of light and shade will be very irregular. There are two different methods of scanning a picture; one is to have one or more electric eyes or photo-electric cells, to give them their proper name, exposed to the whole picture or scene, but to keep the picture in relative darkness, except for one spot which is brilliantly illuminated by a beam of light. This beam of light is caused to scan the picture, and the photo-electric cells are only affected at any moment by the spot on the picture which is illuminated at that moment. The other method is to illuminate the whole scene or picture brilliantly and to focus the photo-electric cell on to one spot of it; this spot is caused to sweep across the picture. In one method the illumination does the scanning; in the other it is done by the electric eye.

Although Mr. Baird has done much towards the development of television, the beginnings of the subject go a long way back, and one of the simplest methods of scanning was invented last century by Nipkow. A thin opaque disc with a number of small holes arranged on a spiral is rotated rapidly in front of an opaque screen having a window on which the picture is focused. The small holes sweep one after the other across this window, only one hole being operative at any moment. In this way a small portion of the picture passes through the hole and falls upon the photo-electric cell, and as the disc rotates the whole picture is scanned. A similar result can be obtained by a number of mirrors arranged on a rotating drum, the successive mirrors being so displaced that they sweep the light across successive strips of the picture.

In the early television experiments the electric eye was made of selenium, an element of the sulphur family, the resistance of which to an electric current varies with the light falling upon it. All modern television depends upon the action of a photo-electric cell, which consists of an evacuated glass bulb having on the inside wall a deposit of a substance such as caesium. A window is left in the glass bulb through which the light passes and falls on the caesium. Two wires pass into the bulb, one connected to the caesium coating and the other to a metal ring or grid arranged so as not to obstruct the beam of light. A battery is connected by its negative terminal to the caesium and by its positive terminal to the grid. In the dark no current passes, but when light falls on the caesium it emits negative electrons which pass across to the grid so that a current passes round the circuit, the strength of which is proportional to the amount of light falling on the caesium. This current is very minute, but it is amplified by means of thermionic valves until it is sufficiently strong to modulate the transmitter.

At the receiving end a neon lamp can be used as the source of light since its brightness can be made to follow the very rapid changes of the received current. If correctly adjusted, its brightness will be proportional at every moment to the brightness of the point of the picture being scanned. The light from the lamp must, however, be made to move over the receiving screen in strict synchronism with the scanning at the transmitter, so that all the variations of light and shade occupy the same relative positions in the original picture and in the reproduction. The way that this was done in the low definition reception was usually by means of a Nipkow disc with its spiral of holes, the discs at both ends being made to run at exactly the same speed and in exact step so that the scanning spot and the reproduced spot

moved together. The motor driving the receiver disc was adjusted as nearly as possible to the right speed, but was then kept in exact step by making the scanning beam at the transmitter sweep a little beyond the picture, and during these short intervals when the beam was off the picture, transmitting an impulse which, since the receiving beam was also off the screen, had no effect on the received picture, but actuated a special synchronous motor, pulling the disc forward if it was lagging or retarding it if it tended to get ahead.

This mechanical method of scanning at the receiver must now be regarded as obsolete; it has been entirely replaced by the cathode-ray tube in which a beam of electrons is emitted from the cathode and caused to travel at high speed to the enlarged end of the tube, which serves as a screen. This screen is coated on the inside with a material which fluoresces under the impact of the electron beam; such materials are calcium tungstate and zinc silicate. The beam is focused electrically so that it gives a luminous spot that is affected in three ways. By applying the received signal, after suitable amplification, to a metal cylinder near the cathode, the beam is varied in intensity, thus causing the brightness of the spot to vary in accordance with the strength of the received signal, and consequently in accordance with the variations of light and shade of the original picture. By applying suitable voltages to pairs of plates in the tube between which the electron stream passes, the beam is given two movements, one being a rapid horizontal to-and-fro movement, and the other a slower up-and-down movement, corresponding exactly to the movement of the eyes when reading a page of a book over and over again, except that the cathode-ray tube scans the page or picture 25 times per second and the page contains about 200 lines. Both of these movements are caused by applying what are called saw-tooth voltages to the deflecting plates; the voltage is that across a condenser which is gradually charged by current flowing through a high resistance; as the voltage rises so the spot is moved across the screen. When the voltage reaches a certain value a valve connected across the condenser suddenly becomes conducting and discharges the condenser, thus causing the voltage to fall suddenly to a low value and the spot to flash back across the screen ready to repeat the process for the next line. As already explained in the case of the Nipkow disc, special synchronizing impulses are sent that control the exact moment at which the condenser discharges, and thus prevent the receiver scanning movements from getting out of step with those at the transmitter.

In addition to televising actual scenes in a studio or out of doors, the equipment at Alexandra Palace includes apparatus for televising films in two different ways. One method utilizes ordinary cinema films, and this is obviously a more easily controllable method than televising actual scenes. The other method employs the film as an intermediate step in televising ordinary scenes; the film is exposed in the ordinary way and passes directly through the processes of developing, fixing and washing; it then passes, while still wet, through the television transmitter. In this way the picture is sent out about half a minute after it actually occurred.

It has been shown why high definition television must be transmitted on short waves if it is not to cause interference over a wide band. Unfortunately, these short waves have a very limited range; they do not bend around the curvature of the earth to a great extent nor are they reflected from the upper atmosphere. Good reception is limited to the area within the visible horizon, and it is for this reason that the first transmitter has been erected at Alexandra Palace 300 feet above sea level and the aerials placed at the top of a tower 300 feet in height. In this way a height of 600

feet is obtained and a correspondingly increased area of service, the estimated range being about 40 miles.

No attempt has been made in this lecture to cover all the recent developments or to describe any one system in detail. Some of the most important developments are of a very complicated nature. The methods described have been chosen because they lend themslvs to discussion by a non-specialist audience, and at the same time give a good general idea of the principles upon which television is based and the lines along which it is being developed.

THE MACHINERY OF THE *SCHARNHORST, POTSDAM,* AND *GNEISENAU.*

In this article extracted from Shipbuilding and Shipping Record, issued February 25, 1937, appears a comparison of characteristics of three new German passenger ships exemplifying the new high pressure, high temperature venture in marine propulsion. Two of the vessels are equipped with electric-drive, and one with geared-turbines, while all are operated at steam temperatures of at least 850 degrees F. It will be interesting to watch them.

An interesting comparison between the principal dimensions and machinery equipments of the Norddeutscher Lloyd's East Asiatic express liners *Scharnhorst, Potsdam* and *Gneisenau* is shown in the table on page 253. These vessels were designed specially to meet the increasingly severe competition for Far Eastern passenger and cargo traffic, and, says Ober-Ing. Erich Schneider in *Hansa,* the innovations introduced and the opportunities provided for comparisons between different equipments in sister vessels are another instance of the active co-operation of German owners with German shipbuilders in advancing practice and accumulating data from service. A full description of the *Scharnhorst* is given in our issue for May 23, 1935, page 575. Originally, it was intended that the Norddeutscher Lloyd should operate the *Scharnhorst* and *Gneisenau,* both built by the Deschimag, A.G. Weser yard; and the Hamburg Amerika Line the *Potsdam,* built by Blohm and Voss; but under the Hapag-Lloyd agreement of January 1, 1935 (Shipbuilding and Shipping Record, February 7, 1935, page 146), the Norddeutscher Lloyd took over the *Potsdam* and assumed sole responsibility for all three vessels.

The dimensions of the *Scharnhorst* and *Gneisenau* are practically identical and both vessels are of Maierform design. The *Potsdam,* however, has a forepart with hollow waterlines, a moderately bulbous bow, and an after part with a heavily-cut-away lateral plan. All three vessels have proved to be steady and free from vibration at all speeds. Turbo-electric propulsion is used in the *Scharnhorst* and *Potsdam,* and high-pressure geared turbines were chosen for the *Gneisenau* in order to compare the relative merits of the two systems. In all three vessels, the steam pressure is far above the usual limits for merchant vessels, the *Scharnhorst* and *Gneisenau* each being provided with four Wagner water-tube boilers operating at 50 atmosphere (711 pounds per square inch) gauge pressure; and the *Potsdam* with four Benson boilers working at 80-85 atmosphere (1138-1209 pounds per square inch) gauge pressure.

WATER-TUBE BOILERS.

In the *Scharnhorst,* the four Wagner water-tube boilers and their auxiliaries are accommodated in a boiler room, between a special auxiliary engine room and (aft) the main engine room containing two turbo-generators and

their auxiliaries. Aft of the main engine room, and separated from it by a provision store, there is the motor room containing the two propeller motors. The general arrangement of the boilers and machinery in the *Potsdam* is similar, except that there is no special auxiliary engine room and no separate room for the propeller motors, the latter and the auxiliaries being all in the same room. The arrangement of boilers and machinery in the *Gneisenau* is in accordance with established practice for geared-turbine propulsion.

The propelling machinery of the *Scharnhorst*, built by the A.E.G., consists of two impulse turbines mounted on their condensers and driving two alternators with air coolers. Each alternator is rated at 10,900 Kw. 3120 volts, 2020 amperes, unity p.f., 52 cycles per second at 3120 R.P.M. The two 3-phase synchronous propeller motors with air coolers are rated as follows:

H.P.	R.p.m.	Volts	Amperes	Cycles per second	P.F.
13,250	130	3,100	1,860	52	1·0
6,625	104	2,480	1,210	41·6	0·95

The four auxiliary generators, main feed pumps and main circulating water pumps are turbine driven, all other auxiliaries being driven electrically.

GEARED TURBINES.

The geared-turbine equipment of the *Gneisenau*, built by the Deschimag, Werk A.G. Weser, consists of two turbine sets, each with high-, intermediate-, and low-pressure turbines for running ahead; also, a high-pressure astern turbine and a low-pressure astern turbine built into the main low-pressure turbine. The auxiliary machinery is of the same type and size as in the sister vessel, *Scharnhorst*, but the boilers of the *Gneisenau* are somewhat smaller than those of the *Scharnhorst* and have a different gas-flow, these changes being based on operating experience with the *Scharnhorst*.

It was found, during the maiden voyage of the *Scharnhorst*, that the high resistance of the air preheaters resulted in excessive back pressure in the combustion chamber, and, the blowers not being capable of developing the requisite air pressure, combustion was affected very adversely. This resulted in rapid fouling of the air preheater, aggravating the trouble, and introducing the danger of burning-through the elements. The difficulty was overcome, after the first voyage, by replacing the air preheater and improving the paths of gas and air flow. The Deschimag-Saacke system of oil-firing is used in the *Scharnhorst* and *Gneisenau*, and, since the remedying of certain initial difficulties, good combustion has been obtained and the regulation of this new type of oil burner has been entirely satisfactory.

The steam-generating equipment of the *Potsdam* consists of four Benson boiler units in an open stokehold with induced- and forced-draught fans. The feed pumps are of the highest importance in the operation of this type of boiler, and there are provided in the *Potsdam* two sets of twin reciprocating pumps of the Balke type and two Klein, Schanzlin and Becker turbo-feed pumps. On the first voyage, the cast-steel valve boxes of the recipro-

PRINCIPAL DIMENSIONS AND PROPELLING MACHINERY OF N.D.L. EAST ASIATIC LINERS

	Scharnhorst	*Potsdam*	*Gneisenau*
Built by	Deschimag	Blohm & Voss	Deschimag
Length, overall	652 ft.	633 ft. 7 in.	652 ft.
Breadth	74 ft. 1 in.	74 ft. 1 in.	74 ft. 1 in.
D.w. capacity, tons	10,510	11,976	10,535
Gross tons register	18,184	17,527	18,160
No. of passengers :—			
First class	149	156	149
Tourist class	144	161	144
Refrigerated space, cu. ft.	48,834	50,846	48,834
Oil tanks, cu. ft.	43,361	45,056	43,361
Propelling machinery	Turbo-electric A.E.G.-Deschimag	Turbo-electric S.S.W.-Blohm & Voss	Geared-turbines Deschimag
S.H.P.	2 × 13,000	2 × 13,000	2 × 13,000
Vessel speed, knots	21	21	21
Steam pressure at turbines :—			
Atmos. (gauge)	45	80	45
Lb. per sq. in. (gauge)	640	1,138	640
Steam temperature at turbines	455° C. (851° F.)	470° C. (878° F.)	455° C. (851° F.)
Main boilers	4 Wagner-Deschimag water-tube	4 Benson Blohm & Voss	4 Wagner-Deschimag water-tube
Boiler heating surface, sq. ft.	4 × 6,994	4 × 6,348	4 × 6,531
Oil-firing : No. of burners per boiler and type	Two Saacke-Deschimag	Four Blohm & Voss	Two Saacke-Deschimag
Combustion air	Closed stokehold Forced draught	Open stokehold Induced and forced draught	Closed stokehold Forced draught

cating pumps gave some trouble owing to porosity at the high pressure concerned (130 atmosphere or 1849 pounds per square inch gauge pressure). This trouble was overcome by substituting mild steel blocks for the cast-steel boxes. The Blohm and Voss oil-firing equipment, with four pressure-atomizers per boiler, is easy to regulate. Smokeless combustion is maintained, soot deposits are slight, and no difficulty is experienced in keeping the equipment clean.

The propelling machinery of the *Potsdam*, built by the Siemens Schuckert Werke, consists of two double-casing reaction turbines; two 3-phase alternators, with air coolers, each rated at 10,000 Kva., 6000 volts, 53⅓ cycles per second, 3200 R.P.M.; and two 3-phase synchronous propeller motors, with air coolers, each rated at 13,000 B.H.P., 6000 volts, 53⅓ cycles per second, 160 R.P.M. All the auxiliaries are electrically-driven excepting the two reserve-boiler feed pumps, and electricity supply for the auxiliaries and deck requirements is provided by four turbo-generators and two Diesel-electric sets.

Notwithstanding the limited amount of previous experience with turbo-electric propulsion in Germany, the maneuvering capabilities of the *Scharn-*

horst and *Potsdam* are "very satisfactory and fulfil all the requirements imposed on merchant vessels of this type." Experience in the operation of the *Scharnhorst* and *Potsdam* was available in time to be applied to the *Gneisenau*, but a certain amount of trouble was nevertheless experienced with the blading of the geared turbines. Increased resistance to wear is desirable in the high-temperature nozzles and blading of the turbines in all three vessels in order to prolong their life and maintain economical steam consumption. The original sea-water evaporating plant was found to be inadequate to the requirements of high-pressure boiler service, but the conversion of the single-stage evaporators to two-stage circulating evaporators and rearrangement of the feed-water treatment have eliminated all difficulties in regard to make-up feed.

Now that the initial troubles have been overcome, "it can be said that the reliability of the high-pressure superheated steam plant is completely assured and a far-reaching improvement in the economy of ship-propulsion has been effected." The zealous co-operation of the engineering personnel of the *Scharnhorst*, *Potsdam* and *Gneisenau* has contributed materially to the attainment of this result.

THE ANNEALING OF WELDED WORK.

This article which appeared in the March, 1937, issue of Machinery, New York, N. Y., was written by Mr. Charles H. Jennings of the Westinghouse Electric and Manufacturing Co. He deals with some of the problems which have developed since stress annealing has been accepted as a necessity in casting and welded assembly work. He sets up a classification for work which need not be annealed, that which should be annealed, and that which should be strain-annealed, and discusses temperatures.

Machine beds, frames, and structures fabricated by the fusion welding process contain a certain amount of residual or locked-up stress as a result of the non-uniform heating and cooling of the parts welded and the progressive solidification of the deposited weld metal. The magnitude of these residual stresses depends upon many factors, such as the type and design of the structure, the rigidity of the joints, the welding process, and the welding procedure.

In addition to creating residual stresses, the fusion welding process also produces metallurgical changes in the parent metals adjacent to the weld. The effect of these metallurgical changes on the service requirements of the joint is dependent upon the type of materials welded, the welding process employed, and the purpose for which the part or structure welded is to be used.

Most annealing operations are employed as a means of relieving residual or locked-up stresses, with no attempt to produce a metallurgical change in the joint. The value and need of strain-annealing some welded structures is open to question, because of a decided lack of knowledge regarding the effect of residual stresses on their service life. Some welding codes consider strain-annealing mandatory on certain classes of structures (see American Society of Mechanical Engineers' Boiler Construction Code for Fusion Welding, and page 129 of the 1935 edition of the American Tentative Standard Code for Pressure Piping sponsored by the American Society of Mechanical Engineers), while others consider it a form of insurance and permit the use of higher joint efficiencies when it is used. (See American

Petroleum Institute—American Society of Mechanical Engineers' Code for Unfired Pressure Vessels, 1934 edition.) In such cases, it is an easy matter for the designer to determine whether or not a structure should be strain-annealed. In the construction of welded machinery and miscellaneous equipment, however, it is often difficult to determine whether strain-annealing is advisable or necessary.

KINDS OF WELDED WORK FOR WHICH ANNEALING IS ADVISABLE.

It is impossible to establish a definite set of rules to determine whether or not a structure should be annealed, but there are certain requirements that will serve as a valuable guide.

1. In general, statically loaded structures and structures composed of light sections, non-rigid connections, and members containing only a small amount of welding *need not be strain-annealed.* Buildings, bed plates, housings, tanks, certain classes of pressure vessels, motor frames, etc., are typical structures of this class.

2. Work that requires accurate machining and that must not become distorted during its service life *should be annealed.* The non-uniform distribution of residual stresses in welded work may cause it to become distorted during machining or warp later as a result of the redistributing of the stresses. Jigs, fixtures, lathe and planer beds, etc., are structures of this class.

3. Parts subjected to dynamic loads *should, in general, be strain-annealed,* because experience has shown residual stresses to be more serious for loadings of this type than for static loadings. Rotors for electrical machinery, Diesel engine crankcases, gears, etc., are in this class. There are some outstanding exceptions in this class of structures, such as bridges, freight cars, locomotive cabs, etc. The latter are generally composed of thin plates or long members containing small amounts of welding; consequently, they can be considered as belonging to the first classification.

4. Structures composed of heavy or large parts and containing large amounts of welding should preferably be annealed, because they generally contain large residual stresses. The Boulder Dam cylinder gates for the intake towers are a typical example of this class of structure.

From the previous classifications, it might appear at first sight that the major portion of all welded structures should be annealed. This, however, is not the case, because most of the structures fall within the first classification. The other classifications actually comprise only a small percentage of all welded structures.

METHOD OF ANNEALING TO RELIEVE STRAINS.

The process of strain-annealing consists essentially of slowly heating the structures or parts to a suitable temperature, allowing them to soak at this temperature for a definite period of time, and then slowly cooling them in the furnace. The annealing temperatures generally used range from 1100 to 1200 degrees F. (This temperature range has been established experimentally and is recommended by all welding codes.) These temperatures are not high enough to produce grain refinement, but they do have a tempering effect, which tends to increase the ductility of the weld and slightly lower the tensile strength. The tempering effect resulting from strain-annealing is often found beneficial in softening hard areas adjacent to the weld, thereby facilitating machining operations.

The theory of strain-annealing to relieve residual stresses is dependent upon three things: First, within certain limits of strain a ductile metal will

not develop a stress greater than its yield point; second, the yield point of metals decreases at high temperatures; and third, the phenomenon of creep, or plastic flow, takes place at high temperatures. (See "The Relief of Welding Strains by Annealing," by Charles H. Jennings, Journal of the American Welding Society, Vol. 10, No. 9, September, 1931, page 26.) The function of these factors during the annealing operation is best explained by an example.

Assume that a welded structure containing residual stresses close to the yield point (30,000 pounds per square inch) of the parent metal is to be annealed at 1100 degrees F. When the temperature of the structure increases above 600 degrees F., the yield point of the material decreases. Also, because the metal will not develop a stress greater than the yield point, provided the amount of plastic strain is small, the residual stresses will also decrease. When the annealing temperature (1100 degrees F.) is reached, the remaining residual stress will be approximately 12,000 pounds per square inch, which is the yield point of the parent and the welding metals at this temperature.

If the structure is cooled uniformly immediately after this temperature is reached, the final residual stress will be 12,000 pounds per square inch. If, however, instead of cooling the structure immediately after it has reached the annealing temperature, it is allowed to soak at this temperature, the phenomenon of creep occurs, and the metal flows plastically, thus further reducing the residual stresses. The longer the soaking time, within limits, the lower the final residual stresses will be.

Test data obtained on welded test plates shows that residual stresses, regardless of their initial values, can be reduced to a negligible amount and that their final value decreases as the annealing temperature increases and the soaking time increases.

Higher annealing temperatures than 1200 degrees F. can be used, but they introduce the problem of excessive distortion, and consequently are seldom used unless required to produce metallurgical changes in the weld or the heat affected areas.

TYPE OF FURNACE REQUIRED FOR ANNEALING.

The annealing process may be carried out in many types of furnaces. These furnaces may be electrically heated, gas heated, or oil fired. In some cases, annealing has even been done in temporary furnaces heated with coke.

When a structure is being annealed, it should be adequately supported to prevent warpage, which may easily occur as a result of the reduced strength of the material at high temperatures. The decreased strength of steels at high temperatures may also be employed to straighten warped structures by properly supporting and weighting them, so that they will sag into the desired form during the annealing operation. This straightening process will not harm the strength of the structure in any way.

The procedure of strain-annealing may vary considerably without greatly influencing its effectiveness. The greatest variations are in the rates of heating and the temperature at which the structure may be removed from the furnace. Some authorities recommend a rate of heating not to exceed 140 degrees F. per hour, while others recommend a rate of heating of 250 degrees F. per hour, or more. The need for extremely slow heating and cooling is obviously more pronounced in annealing structures containing members of widely different thicknesses.

The recommended temperature for removing the structure from the annealing furnace varies from 200 to 400 degrees F. Here again, the deciding factor is the relative thicknesses of the component parts and the design of the structure.

A satisfactory annealing procedure for ordinary welded work made of low- or medium-carbon steels is as follows:

Preparation—Place the welded work in the furnace so as to have the maximum area of surface exposed. Support the structure properly, so that it will not become distorted during the annealing operation.

Heating—The temperature of the furnace should not exceed 300 degrees F. at the time the work is placed in it. Heat the work to 1100 to 1200 degrees F. at a uniform rate not to exceed 200 degrees F. per hour.

Soaking Time—Allow the work to soak at the annealing temperature for a period of at least one hour per inch of thickness of the thickest plate that is welded.

Cooling—Let the work cool slowly in the closed furnace. Below 300 degrees F. the structure may be removed from the furnace and allowed to cool to room temperature in a still atmosphere.

In cases where it is not practicable to anneal the complete structure, annealing of individual joints or parts may be carried out. The annealing of welded joints in high-pressure pipe lines is a typical example. Whenever sectional annealing of a structure is carried out, it is essential that its design be such that the local heating will not produce objectionable residual stresses in other parts of the structure.

ANNEALING TO OBTAIN DESIRABLE METALLURGICAL CHANGES.

In addition to the relief of residual stresses, annealing is sometimes employed to produce corrective metallurgical changes in the welded joints. The annealing temperatures in such cases depend upon the materials the structures are composed of and the nature of the corrective changes desired. Hence, no uniform recommendations can be given as to the annealing temperature, the soaking time, or the cooling rate. The rates of heating specified for strain-annealing, however, will generally be found satisfactory.

The welding of medium-carbon steels (0.30 to 0.45 per cent carbon) and certain alloy steels will generally produce hard areas adjacent to the weld, unless preheating or special welding procedures are used. In such cases, machining of the welded joint may be difficult. Strain-annealing at 1100 to 1200 degrees F. will usually soften these hard areas and thus facilitate machining. Annealing temperatures of 1300 to 1450 degrees F. will further soften the hard areas, but will increase the problem of distortion.

ANNEALING AND AGE-HARDENING ALLOY STEELS CONTAINING COPPER.

Some alloy steels containing copper as an alloying element may be annealed and age-hardened to improve their physical properties. (See A. E. Gibson on "The Development and Use of Low-Alloy High-Tensile Steels," Journal of the American Welding Society, Vol. 14, No. 9, September, 1935, pages 2 to 8.) The increase in strength obtained will depend upon the annealing temperature, the greatest strength being obtained with an annealing temperature of about 950 degrees F. As the annealing temperature increases to 1650 degrees F. the tensile strength is reduced, but the ductility is increased

Welded straight chromium steels of the 4 to 6 per cent and the 16 to 18 per cent grades contain brittle welds and brittle areas adjacent to the welds

as a result of the metallurgical changes resulting from the heat of welding. The ductility of the welds and these brittle areas may be greatly increased by proper annealing.

The maximum softness of the weld and the heat affected zone of 4 to 6 per cent chromium steels is obtained by a full anneal at 1600 degrees F., followed by a slow furnace cooling (about 50 degrees F. per hour) until a temperature of 1200 to 1300 degrees F. is reached. Below this temperature the structure may be air-cooled. The recommended annealing practice for restoring ductility to welded joints in 16 to 18 per cent chromium steel consists of heating to 1450 to 1500 degrees F., followed by slow cooling to at least 1100 degrees F.

The welding of certain grades of 18-8 (18 per cent chromium, 8 per cent nickel) stainless steels produces carbide precipitation which seriously affects the resistance to corrosion. Proper annealing, however, will restore the corrosion resisting properties. The recommended annealing procedure for this type of alloy is to heat slowly to 1900 to 2100 degrees F., followed by rapid cooling.

In all of the previous examples, it will be noted that the annealing temperatures required for metallurgical changes are above the requirements for strain-annealing; consequently, whenever the desired metallurgical changes are obtained, the strain-annealing effect is also produced.

SINGING PROPELLERS.

This is the discussion of a paper read before the North-East Coast Institution of Engineers and Shipbuilders, at Newcastle, England, on February 12, 1937, by Mr. Harry Hunter, O.B.E., B.Sc., which originally appeared in their Transactions. This discussion which briefs down the lecture, appeared in the Marine Engineer, London, England, March, 1937, but to those specially interested, it may be found in full in the Transactions, or in the Shipbuilding and Shipping Record, issue of February 18, 1937.

The design of a screw propeller to develop the correct power at the desired speed of ship and revolutions of engine has always been a difficult problem to the marine engineer. Of recent years, he has been faced with another very obscure phenomenon of propellers—their ability to produce undesirable noise, familiarly known as "singing."

It is well known in the profession that during the last fifteen years a considerable number of cases have arisen in which the propellers were noisy—it is difficult to find any evidence of such in pre-war days, but it seems very likely that they did, in fact, occur. This noise is sometimes very unpleasant, and may interfere with the navigation of the ship, especially in fog, and with the comfort of crew and passengers. Cases are on record of the classification authorities refusing a seaworthy certificate and of owners refusing to take delivery of a ship until the noise was eliminated. The noise in general cannot be called musical, but it does have a brazen characteristic which is generally of a definite pitch, and propellers which emit such noises have come to be referred to as "singing propellers."

Very little has been published on this subject in the past, but Mr. Harry Hunter has now broken this silence by a paper before the North-East Coast Institution. It is to be hoped that others who have information on this problem will impart their own experiences during the written discussion which follows the paper and thus help towards our further knowledge of the phenomenon and in a statistical attack upon it.

Vessel.	A	AA sister ship to A	B	C (6 in all)	D	E and EE (sister ships)	F
Type of ship	Tanker	Tanker	—	Whale catchers	—	Tankers	Passenger
Type of engines	Diesel	Diesel	Geared-turbine	Steam Tr. Exp.	Steam Tr. Exp.	Diesel	Steam Tr. Exp.
Single or twin screw ...	S	S	T	S	T	S	S
Propellers — No. of blades ...	4	4	3	4	4	4	—
Propellers — Material	Bronze	Bronze	Bronze	Stainless steel	Bronze	Bronze	Bronze
Propellers — Type of blade section	Circular back	Circular back	Circular back	Circular back	Aerofoil	Aerofoil	—
Range of revolutions over which noise was audible	65–95	No noise at any speed	80–165	72–103	36–90	85–112	—
Revolutions for maximum sound	80–85		145–150	—	—	—	—
Maximum revolutions of engines	106	,,	200	160–185	97	131	102
Remarks	Slight torsional oscillation at 80–85 r.p.m. None elsewhere in noisy range. With screw from sister ship. AA no noise. Two further screws to same drawing gave better results, last one being accepted.	No noise at all.	Starboard propeller much noiser than Port.	1st and 2nd ships spare screw of cast steel, 3% Nickel, made to same design gave no noise. 3rd and 4th ships stainless steel screw to same drawing but by different makers gave no noise. 5th and 6th ships ordinary cast steel screws gave no noise.	Noise objectionable to passengers. Cast iron propellers of aerofoil section fitted, no noise was experienced.	One screw now reported to have stopped singing. Other continues to sing.	Lead rivets 4" apart and 2" from edge of blade put around each blade. This reduced noise a little. Rivets grew slack and fell out along *trailing* edge. Noise increased again.

For those readers who have not been unfortunate enough to experience a singing propeller, it may be of interest to describe a typical case. At very low revolutions all is generally quiet. The first sign of trouble is usually a grating or grinding noise apparently emanating from the neighborhood of the stern tube. This has all the characteristics to make the investigator believe that it is due to tightness at that point, but investigation has in all cases shown the stern tube to be in good condition. As the revolutions increase the noise changes to a continuous hum, with one or more definite brazen notes or thuds each revolution. This noise usually reaches a maximum and then reduces in volume until, if the propeller can be driven at sufficiently high revolutions, the noise ceases and the screw above this speed is quite quiet. Within the noisy range, the pitch of the note emitted is usually constant and does not vary with the revolutions per minute of the propeller. As regards the volume of sound at the maximum point, this varies greatly between different vessels. In most cases it can be heard right along the shaft tunnel and in the open on the counter, while it is particularly bad in steering gear compartments and similar spaces over the propeller. In bad cases, the singing can be heard on the bridge, and while it may be inaudible forward of this point on deck, can occasionally be heard again in the forecastle spaces.

The cause of this noise is a most difficult thing to trace, and no solution has yet been generally found. The complexity of the problem is increased by the strange differences that occur between sister ships and between port and starboard screws in twin-screw ships. In the latter case, it is, one might say, the exception to find both screws causing the same volume of sound—sometimes nearly all the sound is apparently generated on one side of the ship, but it is extremely difficult to decide this definitely, due to the confined spaces and the conduction of sound along the hull.

Some of these strange effects are brought out by Mr. Hunter in his paper. He gives results for seven ships which suffered from this complaint, and some of the principal items for each have been tabulated here for convenience.

Vessels A and AA were sister ships, having screws made to the same design—A sang and AA did not. The propeller of AA was then tried on A, and there was no noise at all. A new propeller for A was made to the same design and still sang, though not so loudly, and a further one, to the same design but which came out a little heavier and was reported to be a little thicker near the leading edges, was quiet except for a very slight noise between 60 and 70 revolutions per minute.

In vessel B, definite evidence was obtained that one propeller was much noisier than its opposite number.

In vessels C, the strange circumstance arose that, although for four vessels the stainless steel propellers were all made to the same design, two made by one firm sang, while the other two, made by a second firm, were quiet.

If we add to these items the facts that the use of helm affects the noise, and that such propellers have never been found to sing when running astern, we begin to get some idea of the complexities and apparent absurdities of the problem.

One or two general comments can be made on the matter shown in the table. Singing is evidently not associated with any particular class of hull, nor with a particular design of engine, since steam reciprocating and turbine engines appear along with Diesels. The propellers are of bronze, stainless steel, and cast nickel steel, so that it is not possible to place the onus on the material. No cast-iron screw appears in the table, however, and they do appear to be almost immune from this trouble. The appearance of the phenomenon of singing coincided in time with the adoption of aerofoil sections for screw blades, and there has been a tendency to lay the blame upon such sections. It is evident that this is not justified, since in three cases

out of the five for which the screw particulars are given the blades had circular back sections.

To draw any inferences as to the source of the sound is more difficult. One at once obvious is the propeller blades themselves, if they are set into vibration. Each blade will have certain fundamental modes of vibration, each associated with a definite frequency, some of which are in the audible range. The fact that the pitch of the note is usually constant, and of the same order of frequency as is obtained when the blades are struck under water, lends strength to the view that the constant pitch hum is due to the blades vibrating in one of their fundamental Modes. The case of vessel B, in which the pitch varied with the revolutions of the propeller, appears to be unusual in this respect, and it shows that we cannot rule out the possibilities of noises arising from the water or from forced vibrations of the blades.

The report on vessel B, written by members of the staff of the National Physical Laboratory, and summarized by the author, states that the most likely mode of vibration to give notes of the frequency heard on this ship is that in which the whole blade twists in torsion, with a Node down the length of the blade from boss to tip. This is in agreement, to some extent, with the author's experiments on flat propeller blades (that is, blades with no pitch), for he found that the most musical note was given for a vibration which sand tests showed to be torsional with a single nodal line.

The exciting causes of this vibration are no more obvious than the nature of the vibration itself. Torsional oscillation of the shafting has been suspected, but is not now generally held to be in any way responsible. One possibility is that it is analogous to "flutter" in air screws and aeroplane wings. This is a torsional oscillation of the blade or wing, caused either by engine vibration or by the flow over the sections themselves and the shedding of eddies at their trailing edges. As a propeller rotates behind a ship it is in a constantly varying wake, and at some point the slip angle may be such as to set up vibration of this kind at the trailing edge of the blade. The possibility that the vibration arises from this part of the blade is also suggested by the evidence obtained on ship F, as outlined in the table, since the lead rivets which came out, and led to a consequent increase in noise again, were all on the trailing edge. On such a supposition, we should expect aerofoil sections to be rather more prone to singing, since for the same width and thickness they have a longer and thinner section towards the trailing edge. It is on record that certain singing screws of this type, fitted in Holland, were cured when the tip of the aerofoil blade was ground off so as to alter the sections to circular back shape.

Mr. Hunter goes on to discuss the possible connection between singing and erosion or pitting. The latter was investigated in considerable detail by Sir Charles Parsons and Mr. S. S. Cook* and the erosion was then attributed to the mechanical action of vortices collapsing on the blades. Mr. Hunter draws attention to the fact that in all the vessels they dealt with (which were all large and fast ships) no mention was made of any singing, but suggests that the other noises present near the stern of such ships were sufficient to drown it. This may be so, but in that case there could certainly have been no bad case without its being observed.

The author is eventually led to the suggestion that the water forces which set up singing are the same as those which cause erosion, and to support this he states that all cast iron propellers fitted to replace bronze ones which sang have been found to suffer from rapid pitting. The author's conclusions may be briefly summarized under three heads.

* "Investigations into the Causes of Corrosion or Erosion of Propellers," by Hon. Sir Charles Parsons and Mr. Stanley Cook. Trans. I.N.A. 1919.

1. The exciting force is probably due to eddies. These may be shed by the blades themselves from the trailing edge, or result from the breakdown of the flow on the back near the leading edge because of excessive slip angles at some point in a revolution. Alternatively, they may be shed by the hull, bossings or A brackets ahead of the propellers.

2. Physical properties of the metal, such as a modulus of elasticity and elastic hysteresis, may have some effect on the responsiveness of the propeller, while its method of manufacture, heat-treatment after casting, and the composition of the alloy may also be important.

3. It seems possible that to ensure a quiet propeller, the accuracy of the finish of the screw must be of a high order.

A survey of our present knowledge, as set out by Mr. Hunter, shows the extreme difficulty of the problem. There are obvious sources of vibration and noise, and there are also plenty of disturbing factors which may excite such vibration. One begins to feel that it is surprising that all propellers do not sing. It is very obvious, also, that the conditions which set up singing are very critical, as instanced by the difference between sister ships, one so bad that she is neither accepted by her owners nor granted a seaworthy certificate, the other perfectly quiet, and between port and starboard screws of a twin-screw ship. This makes it extremely difficult to draw any conclusions from the evidence offered, and for a ship with a really bad singing propeller there still seems to be only one certain and immediate cure—the substitution of a cast iron screw. This is an unsatisfactory state of affairs, and a costly one to engineers, propeller manufacturers, and owners, and it is to be hoped that Mr. Hunter's ventilation of the question at Newcastle will elicit further information which will help towards a satisfactory solution of this difficult problem.

MISCELLANEA OF INTEREST TO NAVAL ENGINEERS.

PROPELLER PROTECTION. Shipbuilding and Shipping Record, London, England, January 28, 1937.

The prevention of erosion at the back of cast-iron propellers has been the subject of experiments for a considerable time and attempts, often at considerable expense, to stay the progress of this deterioration have met with varying success.

A patented method of protection, which is claimed to resist erosion, corrosion or electrolytic action, has been patented by Friedenthals Limited, Preston, and consists of covering the propeller blades with vulcanite by a special process. As an experiment, two of the blades of a four-bladed cast-iron propeller of a trawler were treated with the protective covering and were stated to show no signs of corrosion after 14 months work.

RADIUM FROM THE ARCTIC CIRCLE. Briefed from Inco, New York, N. Y., Vol. XIV, No. 4.

To the aeroplane, which has uncovered so many of Canada's rich natural resources in the Northwest Territory, belongs credit for having developed the Western Hemisphere's foremost source of radium.

More than 1100 air miles due north of Edmonton, Alberta, on the shores of Great Bear Lake, the deposit lies far beyond the railway outposts. For

TABLE SHOWING THE WORLD'S SHIPBUILDING FROM 1893 TO 193

THE WORLD'S SHIPBU

SHOWING THE NUMBER AND TONNAGE OF MERCHANT VESSELS OF 100
VARIOUS COUNTRIES OF THE WORLD DURING THE

Year.	Great Britain and Ireland.		British Dominions.				Austria-Hungary.		Denmark.		France.		Germany.		Holland.		Italy.		Ja
			Consts.		Canadian Lake Ports.														
	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.
1893	536	826,383	41	17,089	No	Returns	6	7,435	18	10,719	22	20,337	65	60,167	6	1,239	21	10,626	2
1894	614	1,046,508	26	6,055	1	748	5	1,703	16	7,300	28	19,636	77	119,702	41	15,260	10	5,296	14
1895	579	950,967	23	6,105	7	4,276	10	71	14	10,962	27	28,851	75	87,786	25	8,292	10	5,603	3
1896	606	1,159,751	36	8,394	5	2,730	9	6,246	14	11,814	41	44,565	63	103,295	28	12,405	10	6,779	26
1897	591	952,486	36	10,439	4	1,942	6	6,601	13	13,530	39	49,341	84	139,728	42	20,351	8	12,910	22
1898	761	1,367,570	65	22,664	5	2,357	9	5,432	17	12,703	48	67,100	104	153,147	27	19,468	19	26,530	9
1899	726	1,416,791	31	6,475	3	1,989	8	9,248	30	26,613	51	89,794	93	211,664	50	34,394	31	49,472	3
1900	692	1,442,471	38	6,967	2	2,596	12	14,889	17	11,060	66	116,858	93	204,731	61	45,074	36	67,522	3
1901	639	1,524,739	68	16,610	6	11,524	7	20,013	41	22,656	92	177,543	101	217,593	33	29,927	35	60,526	94
1902	604	1,427,558	65	18,235	4	10,584	16	15,192	44	27,146	99	192,196	106	213,961	114	69,101	62	46,270	53
1903	697	1,190,618	64	20,866	9	13,824	6	11,328	39	28,609	75	92,766	120	184,494	109	59,174	81	50,099	62
1904	712	1,205,162	55	27,253	6	3,712	40	16,645	30	15,859	69	81,245	149	202,197	109	55,686	35	30,016	67
1905	795	1,623,168		45	—	10,796	27	14,402	19	17,557	43	73,124	148	255,422	58	44,135	46	51,629	81
1906	866	1,828,343	50	16,026	7	10,016	25	13,590	18	24,712	46	35,214	205	318,230	89	66,209	30	30,560	107
1907	841	1,607,800	83	21,479	14	24,964	7	8,717	29	29,819	50	61,635	188	275,003	60	65,623	31	44,666	78
1908	522	929,669	111	25,512	8	8,699	24	23,503	24	19,172	50	83,439	120	207,777	76	58,604	34	26,864	73
1909	536	991,066	35	6,502	2	969	15	25,006	11	7,508	51	42,197	84	128,696	52	39,106	28	31,217	75
1910	509	1,143,169	53	14,601	7	11,742	8	14,304	18	12,154	55	80,751	117	159,303	105	70,945	21	23,019	70
1911	772	1,603,544	59	16,006	3	3,656	16	37,230	18	18,669	79	125,472	154	255,532	113	93,050	14	17,401	109
1912	712	1,736,514	76	25,090	8	9,700	12	26,821	22	26,103	80	110,734	165	375,317	112	99,439	27	25,196	106
1913	688	1,833,153	77	26,744	14	21,585	17	61,757	31	40,932	89	176,095	162	465,226	95	104,296	38	50,356	152
1914	656	1,683,553	58	22,238	22	25,246	11	34,335*	25	32,815	32	114,052	89	387,192*	130	118,153	47	42,981	32
1915	327	650,919	27	13,280	4	8,725	No	Returns	23	45,198	6	25,402	No	Returns	120	113,075	30	22,132	26
1916	306	606,235	36	22,577	4	8,994	No	Returns	28	35,277	9	42,752	No	Returns	201	180,197	10	56,654	55
1917	286	1,162,906	80	66,475	25	27,996	No	Returns	23	20,445	6	18,828	No	Returns	146	148,779	11	38,906	104
1918	301	1,348,120	184	230,514	22	49,380	No	Returns	13	26,150	3	13,715	No	Returns	74	74,026	15	60,791	196
1919	612	1,620,442	235	298,495	28	60,233	—	—	46	37,766	34	32,663	*	*	100	137,066	28	82,713	153
1920	618	2,055,624	90	174,557	13	29,087	—	—	30	60,669	50	93,449	*	*	99	183,149	32	133,100	140
1921	426	1,538,052	49	116,303	5	11,372	—	—	57	77,238	65	210,663	242	509,064	98	232,402	35	164,746	43
1922	235	1,031,061	37	53,347	2	9,416	—	—	23	41,016	62	184,509	195	575,384	60	163,132	43	101,177	49
1923	222	645,651	41	37,072	3	4,191	—	—	24	49,479	27	96,644	117	358,273	35	66,682	21	66,523	44
1924	494	1,439,885	29	29,815	2	15,064	—	—	33	63,937	36	79,685	136	193,963	41	63,637	19	52,596	31
1925	342	1,064,633	47	35,220	4	12,856	—	—	21	73,266	35	75,509	127	418,048	47	78,823	31	142,046	23
1926	197	639,568	39	22,842	3	10,836	—	—	25	72,106	34	121,342	60	180,546	47	93,671	27	230,021	36
1927	371	1,225,873	24	20,119	5	10,131	—	—	20	72,038	22	44,335	105	589,622	68	119,790	25	101,076	19
1928	420	1,445,920	47	22,959	1	734	—	—	31	138,712	20	81,416	81	376,416	74	166,754	29	58,640	37
1929	489	1,522,623	47	21,327	3	11,814	—	—	34	111,496	16	81,607	85	249,077	77	126,517	22	71,497	40
1930	481	1,478,563	77	43,292	2	458	—	—	26	137,230	18	100,917	92	245,567	74	153,072	28	87,709	37
1931	148	502,487	31	13,612	—	—	—	—	20	125,974	22	103,419	56	103,924	99	120,226	33	165,048	42
1932	100	187,794	14	3,424	2	1,336	—	—	18	23,413	23	39,310	15	30,790	30	28,232	9	47,441	44
1933	106	133,115	20	12,956	—	—	—	—	19	24,016	29	34,078	43	42,196	25	38,289	3	16,560	20
1934	173	459,877	16	9,112	—	—	—	—	21	61,729	10	15,950	57	73,733	31	49,905	6	28,639	155
1935	185	499,011	28	10,047	2	1,142	—	—	33	122,096	10	42,783	78	226,343	48	57,133	4	22,667	177
1936	328	856,257	25	6,230	—	—	—	—	35	97,537	17	30,208	161	379,981	69	69,831	7	11,245	180

SHIPBUILDING.

LS OF 100 TONS GROSS AND UPWARDS LAUNCHED IN THE RING THE YEARS 1893–1936.

aly.		Japan.		Norway.		Sweden.	United States.				Other Countries.		Totals.		Year.
							Coast.		Great Lakes.						
Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	
10,626	3	1,132	30	16,552	16	6,566	36	27,174	No	Returns	42	11,222	846	1,024,741	1893
5,206	14	3,173	25	17,160	14	7,310	36	44,847	7	22,047	18	6,564	932	1,223,539	1894
5,603	3	2,296	21	12,873	13	2,767	41	42,431	20	42,446	12	5,114	890	1,216,160	1895
6,779	26	7,849	17	12,059	14	4,405	112	77,964	32	106,211	10	3,415	1,113	1,567,882	1896
12,910	22	6,740	25	17,248	14	6,964	63	34,076	21	52,762	22	6,727	900	1,231,934	1897
26,530	9	11,424	29	22,670	12	4,385	141	110,186	21	63,064	23	4,582	1,290	1,893,243	1898
49,472	3	6,775	34	27,853	29	10,367	127	146,103	21	68,170	32	6,015	1,269	2,121,738	1899
67,522	3	4,543	42	32,751	19	5,735	196	190,902	39	142,565	48	15,439	1,364	2,304,163	1900
60,526	94	37,208	40	36,875	31	8,241	234	268,001	82	165,144	65	20,649	1,538	2,617,539	1901
46,270	53	27,181	46	37,878	32	9,080	206	223,360	45	155,814	62	22,247	1,650	2,502,755	1902
50,089	62	34,514	54	41,599	30	11,855	195	211,219	51	170,601	58	24,073	1,650	2,145,631	1903
30,016	67	32,969	67	50,469	32	10,267	208	189,430	19	49,086	45	17,987	1,643	1,997,935	1904
31,629	81	31,725	58	58,580	20	5,282	157	107,368	43	195,459	36	20,272	1,576	2,514,922	1905
30,560	107	42,489	69	60,774	23	11,579	192	169,358	50	271,729	37	15,334	1,836	2,919,763	1906
44,666	78	66,254	82	57,556	25	11,781	208	217,530	47	257,145	42	26,026	1,788	2,778,068	1907
26,864	73	59,725	81	52,339	23	9,546	202	158,645	36	145,886	20	23,435	1,405	1,833,286	1908
31,217	75	52,319	45	28,601	12	6,216	73	80,485	29	129,119	24	12,960	1,063	1,602,057	1909
23,019	70	30,215	64	36,931	17	8,904	150	177,601	29	153,717	47	20,497	1,277	1,957,853	1910
17,401	109	44,360	71	35,435	11	9,427	112	95,692	30	75,876	36	17,264	1,599	2,650,140	1911
25,196	168	57,755	89	50,255	22	13,908	144	194,273	30	89,960	52	46,654	1,719	2,901,760	1912
50,356	152	64,664	74	50,637	25	18,524	182	228,222	22	48,216	83	43,455	1,750	3,332,862	1913
42,981	32	38,861	61	54,204	26	15,163	84	162,937	10	37,825	35	36,148*	1,319	2,852,753*	1914
22,132	28	49,406	59	62,070	27	20,319	76	157,167	8	20,293	10	13,641*	743	1,201,638*	1915
56,654	55	145,624	52	42,456	24	25,760	167	384,999	44	119,348	18	14,296*	964	1,668,060*	1916
33,908	104	250,141	44	46,103	24	25,760	286	821,115	60	176,804	27	22,538*	1,112	2,937,786*	1917
60,701	166	486,924	51	47,722	28	39,583	741	2,602,153	166	430,877	40	34,478*	1,886	5,447,444*	1918
62,713	183	611,883	62	57,878	53	50,971	853	2,579,836	199	496,559	77	79,334	2,463	7,144,549*	1919
133,190	149	456,642	30	38,955	46	63,822	467	2,345,725	42	127,523	52	96,368	1,750	5,861,666*	1920
164,748	43	227,425	35	51,458	27	65,911	166	906,129	7	11,284	22	128,630	1,377	4,341,679	1921
101,177	49	83,419	23	32,291	14	30,038	55	97,161	4	21,977	51	43,154	952	2,467,064	1922
66,523	44	72,475	48	42,619	10	20,118	69	96,491	14	76,228	30	11,687	701	1,643,181	1923
62,536	31	72,757	34	25,139	12	31,211	71	90,155	8	49,308	8	10,690	924	2,347,751	1924
142,046	23	55,784	48	28,805	17	53,750	94	76,706	7	50,010	12	7,824	855	2,198,404	1925
230,021	36	52,405	25	9,237	14	53,513	73	115,217	5	35,398	25	48,288	800	1,974,977	1926
101,076	19	42,359	12	5,363	18	67,361	58	124,270	8	54,948	47	106,394	902	2,285,769	1927
58,640	37	103,663	13	10,401	20	106,912	57	88,062	6	5,265	34	95,255	969	2,609,239	1928
71,497	40	164,467	51	39,804	29	107,246	59	100,632	4	25,431	46	99,852	1,012	2,795,210	1929
87,709	37	151,272	53	58,943	31	131,781	92	214,012	8	32,675	45	59,091	1,084	2,899,472	1930
165,048	42	83,721	20	18,163	20	112,703	55	203,227	2	3,638	26	61,893	906	1,617,115	1931
47,441	44	54,423	8	11,129	12	43,000	18	143,550	—	—	15	15,732	307	726,501	1932
16,560	20	74,280	7	9,715	14	60,880	14	10,771	—	—	18	24,541	330	489,016	1933
36,638	155	182,420	12	18,857	12	49,542	21	24,625	—	—	23	28,031	536	987,419	1934
22,667	177	145,914	23	25,716	22	105,538	14	32,607	—	—	25	11,084	640	1,302,080	1935
11,345	190	294,261	33	33,162	33	154,044	57	101,256	12	10,627	42	30,574	900	2,117,924	1936

about six weeks each year it can be reached by navigating the MacKenzie River for a distance of 1275 miles from the nearest railhead. The rest of the twelve months the way is covered by trackless snow. But the airlanes are open save during the fall and spring periods of freeze and thaw when pontoons or skis cannot be used for take-off or for landing.

Prompted by encouraging reports of earlier geological surveys of the district and urged on by the established facilities of the plane for exploratory and development projects in the northern bush, Gilbert La Bine, a prospector of long experience, set out for Great Bear Lake in the summer of 1928. He travelled the air mile distance—which by ordinary means of transportation would require many months—in an amphibian plane which landed him on the lake a few hours after take-off. After several days' scrutiny of the shore line, with the aid of a collapsible boat, he found a mass of rock stained with cobalt-bloom and copper green. Examination of these rocks revealed not only cobalt and copper, but silver and other metals as well. And, also, pitch-blende, the ore from which radium is recovered.

Today, the Eldorado Mines, Ltd., formed to develop this property, has rounded out its third year of production at its radium refinery at Port Hope, Ontario. By the end of 1936 it had completed production of its first ounce of radium. Only the pitch-blende is refined here. The other ores, including the silver, are sent elsewhere.

Prior to the time the Port Hope refinery began its operations there were only three grams of radium in Canada—it takes 28.35 grams to make an ounce (avoirdupois). Because the total capacity of the refinery, as developed up to the first of this year, is only about 28 grams a year, facilities are now being tripled. Before Canadian production was started the price of radium was $70,000 a gram and the market was controlled by a Belgian company whose ores came from mines in the Belgian Congo. The present price is about $30,000 a gram, or roughly, $840,000 an ounce (avoirdupois).

When navigation is possible on the MacKenzie River, ore from the mines is shipped by boat. During the rest of the year it is carried out by airplanes and the average freighting cost of a ton of ore delivered at the railhead is $65. It requires one ton of ore to produce 90 milligrams of radium or approximately 25/1000 of an ounce.

Refining the pitch-blende is essentially a series of chemical operations. Initial steps in production are much the same as those taken in the refining of other metals. The ore is crushed and roasted to remove sulphur. Refinement then proceeds by hydro-metallurgy, or wet process, as distinguished from smelting and the "dry" method. Operations consist of chemical processing, leaching and filtering.

These result in the recovery of uranium, lead, and silver. Uranium, like radium a radio-active material, is widely used as a pigment in the coloring of ceramics. Lead from pitch-blende ore resembles commercial lead, though it is slightly greater in atomic weight and is largely used in scientific work. It is partly a product of the disintegration of radium, though it is not known just what proportion of the lead is thus formed.

Disintegration of radium proceeds at a slow rate. Its exact life period is uncertain. However, it has been found by calculations from laboratory measurements of the loss of radio-activity that, on the average, one-half of a given amount of radium will turn to lead in 1700 years.

Besides the uranium, lead and silver—the latter runs about 1000 ounces to the ton of pitch-blende—copper, manganese, and a certain amount of iron are removed in the various processes.

In the earliest stages of operation steps are taken to safeguard the radium content of the ore. This is done by the addition of barium, which has a

strong affinity for the elusive element. Through one after another of the scores of operations necessary before actual refining of the radium takes place they remain together in one chemical form or another. Roughly, the proportion of barium to radium is 5000 parts to 1.

Finally, in the form of barium-radium bromides the two elements are sent together to the finishing laboratory where the first efforts are made to break up their association. In a slightly alkaline solution they are placed in Monel pails and cooked over open gas flames for the first of a series of fractional crystallizations.

When the saturated solution reaches its boiling point the pail is cooled, allowing barium-radium bromide crystals to deposit in the bottom. Some of the barium bromides remain in solution. Further chemicals are added and the process continues, the mixed crystals becoming richer and richer in radium and smaller in barium. The sizes of the evaporating dishes decrease until at last a 3-cubic centimeter crucible—about the size of a thimble—holds crystals containing approximately 9 parts radium bromide to 1 part barium bromide, very much resembling ordinary table salt in appearance. These are dried and sealed in small glass tubes about the size of a match, each containing about $2000 worth of radium—still with some of its tenacious barium present. Strictly speaking, no pure radium is ever produced. The slight amount of impurities remaining, however, does not affect its value for medical purposes.

The glass tubes are shipped in lead cartridges, first for official measurements in Ottawa and then to London where the radium-bromide is transformed into sulphate and distributed in sealed metallic containers of various designs used for medical applications. An alloy of 90 per cent platinum—10 per cent iridium—is generally used, but containers made of 75 per cent platinum—25 per cent iridium—gold, silver or Monel are also supplied.

For the treatment of cancer, by radium, a number of different methods are employed. The most common one is by means of needles which are usually made of 10 per cent iridio-platinum and consist of an inner cell and an hermetically-sealed outer sheath with an eyelet. One of the chief reasons for using this platinum alloy is because of its screening effect. It screens out the alpha, beta, and some of the softer gamma rays. Its resistance to tarnish is also important.

For some special cases, needles with as little screenage as possible are required. These are usually made of Monel tubing 0.3 millimeters (about .012 of an inch) in thickness and the effect is to let a large proportion of the beta rays through.

Another means of treatment is by plaques. These are rectangular or circular boxes about one or two millimeters (.08 of an inch) deep which are made either of gilded brass or of Monel. In almost every case, the face is made of a Monel sheet, very thin, usually about .05 millimeters (.002 of an inch) in thickness. The inner side of this face is a thin slip of mica.

There is now a trend in the direction of using bombs which contain much greater quantities of radium than either of the other two types of applicators. This is, so far, pretty much in the experimental stage.

FIREBRICK LININGS. Shipbuilding and Shipping Record, London, England, January 28, 1937.

In the furnaces of marine boilers, particularly those of boilers of the water-tube type, firebrick linings are employed to protect the steel plates against the effect of contact with the flames of the burning fuel. It is well

known that the edges of these bricks, and often the cement used to connect them together, suffer disintegration in consequence of the high temperatures to which they are subjected, and as a protection against this, it is becoming a common practice to coat the entire firebrick linings with a layer of plastic refractory material, thereby forming a smooth monolithic surface. This material has hitherto been applied by means of a trowel or a brush, but with a view to reducing labor costs, and at the same time to obtain a more penetrative and uniform surface, a well-known British firm which specializes in the production of these refractories has placed on the market a special fire-cement gun which is capable of building up an unbroken coating of any desired thickness up to ½ inch in one operation. The gun is operated by means of compressed air at a pressure of 40 to 50 pounds per square inch, and sprays the cement, which has previously been mixed to a cream-like consistency from a distance of 3 to 4 feet, causing it to penetrate into interstices which cannot be filled with brush or trowel, and yielding a hard semi-glazed surface which reduces the leakage of heat, as well as preserving the firebrick. It is claimed that the furnace can be lighted up, if desired, immediately after the cement coating is completed.

STATIONARY GAS WAVES IN DETONATING PETROL ENGINES. Engineering, London, England, February 5, 1937.

Detonation in petrol engines is generally considered to be a combustion caused by self-ignition of the end gas, i.e., the last part of the mixture to burn. Its manifestation has been reported by some as a local excessive pressure, by others as a gas vibration. Experiments have shown, however, that in some engines detonation may occur without causing either of these phenomena. We have received a very interesting report on work carried out at the Delft Laboratory by Messrs. G. D. Boerlage, J. J. Broeze, Dr. H. von Driel and L. A. Peletier which throws further light on the subject. We propose to publish this report in an early issue, but in the meantime, may say that the authors have carried out experiments with pressure measurements at nine places on an L-head engine. These have shown that, in this engine typical stationary gas waves always accompany detonation. It was found that of the possible types of vibration the one with the lowest frequency, i.e., a longitudinal wave, predominates. Regardless of the spot or spots where the spark occurred, the nature of the vibration was found to be substantially the same. The distribution of the wave amplitudes had a typical character, which may be ascribed to the peculiar distribution of the volumes throughout the combustion chamber. It may therefore be suggested that the vibration amplitudes are very largely a function of combustion-chamber shape. In particular, flat clearance spaces in L-head engines may lead to local high amplitudes: any velocity of gas towards such narrow clearances must build up pressure which may be compared to an effect such as a river "bore." It is striking that at the spot where this effect occurred, pistons had frequently cracked in this engine due to prolonged heavy detonation. These fractures may therefore be ascribed to a fatigue effect. In none of these experiments was an initial "burst" of excessive pressure found where the end gas exploded. An important conclusion is that definite distinction must be made between (*a*) the spot where the end gas actually explodes, (*b*) the spot where the maximal pressure vibration effect occurs, and probably (*c*) the spot where the heat effect of the detonation is greatest. Correlation of the pressure vibrations with flame vibrations shown by photographs and with the local heat effects of detonation are being investigated.

REGULATING SUPERHEAT TEMPERATURE. Shipbuilding and Shipping Record, London, England, April 8, 1937.

When a steamship is proceeding normally on its voyage at uniform speed, the demand for steam from the boilers is constant and thus a uniform superheat temperature is easily obtained. During maneuvering, however, or at any other time when the demand for steam fluctuates, the superheater elements in the boilers are necessarily exposed to the more or less uniform furnace temperature and hence a wide fluctuation in the superheat temperature will result. Apart from the evil effects of very highly superheated steam, an undue rise of temperature of the superheater elements themselves may occur with possibly serious consequences. It is apparent therefore that some system for regulating the superheat temperature is very desirable. This can be readily effected by means of an attemperator, which permits of the mixing of live steam direct from the boiler with the superheated steam, and automatic control device being provided in order to ensure that a practically uniform temperature is obtained. In one system fitted by a well-known firm of makers of marine water-tube boilers, the attemperator consists of a number of U tubes through which part of the steam is passed, these tubes being immersed in water taken from the boiler drum. The portion of steam passing through the tubes is controlled by a thermostat placed in the main steam pipe immediately in front of the main stop valve. Thus, any rise in the superheat temperature causes a greater quantity of steam to be passed to the attemperator, and the steam thus generated in the attemperator is passed back to the boiler drum. It is claimed that this arrangement results in a very close regulation of the final steam temperature.

NOISE IN ENGINE ROOMS. British Motor Ship, London, England, February, 1937.

Warfare is being waged against undesired noise in many directions, but there is scope for more energy among engineers, shipowners and shipbuilders to combat this "torture to all intellectual people," as Schopenhauer termed it. It is not often that experiments are carried out in engine-rooms of ships to ascertain the degree of noise and compare it with that in other vessels; hence the investigations made in the motor ship *Athen* are of some importance.

Their special value lies in the fact that, in the vessel in question, there are two relatively high-speed engines driving a single propeller through gearing, and it might be anticipated that the noise would be more than in the average motor vessel with direct drive. It was found that at full speed the degree of loudness was 102 phons, and that when a single engine was running the measurement showed 99 phons. When developing maximum power on the measured mile the figure rose to 110 phons. Similar tests in a ship equipped with a 4100 B.H.P. double-acting two-stroke engine with direct drive, and running at 116 R.P.M., gave a result precisely similar to that in the geared Diesel ship.

It is assumed from these results that the degree of noise in two engines is only slightly greater than that of one, and that, moreover, noise depends not so much on the number of cylinders and engines, but on the noise of that particular cylinder and its gearing from which noise is developed.

It will not surprise those who have had much experience with motor ship engine-rooms to know that two four-stroke high-speed engines registered 95 phons, which was as high as with a single propelling engine running at 170 R.P.M. and developing 1500 B.H.P., or four times the power of the auxiliaries.

We suggest that further experiments be made in which the shipowners, shipbuilders and marine engineers cooperate. It is by no means certain what is the main cause of noise, nor how it can best be ameliorated. The arrangement of the exhaust, the location of the main and auxiliary engines in relation to the hull, the vibration of the plating and many other factors may come into consideration. With the advance that has lately been made in sound measurements, there should be no difficulty in investigating the problem scientifically in various ships with different classes of engine, and as a result of the data which would thereby be accumulated we feel assured that the noise in the average engine-room could be substantially reduced.

No doubt most of our readers are familiar with the meaning of the term "phon." It is an arbitrary standard to indicate the relative loudness as it affects the human ear. The unit of measurement which indicates in absolute terms the energy content of a given sound is a decibel.

To put it broadly, the phon is a subjective unit indicating the degree of loudness or intensity as perceived by the human ear. The manner in which it is established is as follows:—The number of decibels of a note of a thousand cycles, whose loudness is judged to be equal to that of the note measured, is equal to the number of phons of the measured note.

As a comparative measure indicating the degree of loudness in relation to that of other noises, it may be recorded that the noise in a boiler factory is reckoned at about 106 phons, in an underground car at 102 phons, and in an untreated aeroplane cabin as 94 phons. The average whisper is represented by 20 phons.

THE *NORMANDIE'S* NEW RECORDS. The Engineer, London, England, March 26, 1937.

During the twenty-four hours which ended at noon on Saturday, March 20th, the *Normandie*, of the French Line, which left New York on Thursday, attained the highest average speed ever made in a day's run by a mercantile ship. Her day's average was 728 nautical miles, at an average speed of 31.65 knots. The previous record for the east-bound passage was gained by the *Queen Mary*, of the Cunard White Star Line, in August last, when she steamed 713 nautical miles in a day at an average speed of 31 knots. A further record was gained by the *Normandie* on Monday when she passed the Bishop Rock at 42 minutes 56 seconds past six o'clock, covering the 2967 miles from the Ambrose Lightship in the record time of 4 days 6 minutes 23 seconds, at an average speed of 30.99 knots. When in August last the *Queen Mary* gained the record for the east-bound passage on the official course, her time from the Ambrose Lightship to the Bishop Rock was 3 days 23 hours 57 minutes, at an average speed of 30.63 knots. It may be recalled that the *Normandie's* previous record was 4 days 3 hours 28 minutes, at an average speed of 30.31 knots. During the recent overhaul of the *Normandie* the generating sets and the propelling motors were thoroughly overhauled and adjusted, and new propellers were fitted. The records above referred to are more noteworthy on account of the fact that the voyage was made in winter, and that during the voyage March winds and snow were encountered. We are given to understand that the machinery was run at normal revolutions throughout the trip.

WOOD PRESERVATION. The Engineer, London, England, April 2, 1937.

A new method of wood preservation has been patented in Germany. The material used is a silicic acid ester of phenols, alone or in a solution or

mixture with other substances. The moisture contained in the wood splits the ester hydrolytically into silicic acid hydrates and free phenols. To accelerate the hydrolytic action and to promote formation of hard, almost insoluble, compounds, the wood itself or the preservative liquid is treated with water, ammonia, or solution of salts of alkaline-earth metals. This may be done before, during, or after impregnation of the wood. The treatment is claimed to improve physical properties of the wood and to make it immune against decay fungi, owing to the toxic action of phenol.

SUPERSONIC WAVES FOR NAVIGATION. Shipbuilding and Shipping Record, London, England, April 15, 1937.

A paper presented to the Nautischer Verein, Bremen, by Direktor Dr. Kuntze, deals with the navigational applications of ultra-short sound waves. The requisite high frequencies are obtained by utilizing the phenomena of magnetostriction and piezeo-electricity, namely, the property of certain metals, particularly nickel, and certain crystals of being set in vibration by the passage of alternating current. The special advantage of the supersonic waves lies in the strongly marked directional effect obtainable by proper adjustment of radiating surface and wave-length. In the course of his address, Dr. Kuntze deals particularly with the new Periphon apparatus developed by the Atlas Werke, employing a supersonic emitter and receiver about 1 foot in diameter, attached to the bottom of the forepart of the vessel and rotated from the bridge. Used as a directional detector, this apparatus enables the bearing of lightships, buoys or other transmitters to be determined accurately within 1 degree. Apart from this, and its use in locating other vessels by their propeller vibrations, the new supersonic apparatus is claimed to be specially useful in determining the distance of rocks, anchored vessels, or other obstacles by a process of "horizontal echo-sounding," using the directional short waves. It is expected that the results of trials now in progress in vessels equipped with the new gear will confirm its value as an aid to navigation in fog. Recommendations as to the standardization of supersonic frequencies for lightships, buoys and the like are to be presented at the forthcoming International Conference of Sea-Mark Engineers in Berlin.

MACHINE GUN MOLDING. Industrial Bulletin of Arthur D. Little, Inc., Cambridge, Mass., April, 1937.

The continuous production of molded plastics from a single molding machine at a rate of "hundreds per minute" rather than "per hour" appears to be one of the most promising new developments in the plastics field.

As yet commercial production has been only on relatively simple shapes such as buttons, rectangular blocks and bottle cap tops, and it appears that the process is particularly suited for the production of pieces of this sort having a practically uniform cross section in one direction and in which a high degree of flow in the mold is not required. On shapes that can be handled by this process, molding costs can be reduced to a fraction of those possible with the conventional hydraulic press as normally used by the custom molder.

The new molding operation is entirely automatic, as contrasted with the previous practice for forming such small parts, in which the molding cycle requires holding the press open for filling the mold cavities by hand with pre-formed tablets of composition, closing the press for the molding cycle by manual controls, and then opening for ejection. In the new process, mold-

ing composition in granular form is fed into a hopper on the machine and continuously converted to a series of molded pieces which are shot out, at the injection stage, with machine gun rapidity.

The molding machine is a modification of a heavy duty rotary tabletting machine of the same general design as is used for making pharmaceutical tablets and candies such as "Life Savers." The molding composition feeds from the hopper on this machine into a rotating turret containing several mold cavities. At subsequent positions of the turret, the mold is closed, the full forming pressure exerted, and the mold opened for ejection.

On pieces such as bottle-cork tops, commonly used on ink bottle corks, a production rate of 600 pieces per minute is reached, while on smaller pieces such as buttons, where several mold cavities can be made per station, the production can be stepped up proportionately.

Considerable latitude is possible in the physical properties of the compositions which can be handled by this process: in general, the range being roughly from compositions of the cold molding type to those giving a product having many of the characteristics of hot molded thermal setting resins. Moldings from the latter type of compositions are heat cured in bulk after the molding operation. While the finish of the parts is excellent as it comes from the mold, conventional tumbling operations may be used to further improve the appearance.

It is interesting to note that cold molding compositions similar to those used in this process were covered by patents so old that they have now expired, taken out in the names of a number of the famous early workers in the field of synthetic resins. Their commercial use does not appear to have been as extended as might have been expected from the nature and cost of these compositions, due to a number of practical operating difficulties. These, it is reported, have now been overcome by improvements in composition and methods of handling.

CUTTING WEIGHTS IN WARSHIPS. Shipbuilding and Shipping Record, London, England, February 25, 1937.

The naval clauses of the Treaty of Versailles strictly limited the size of the various types of German warships to a maximum of 10,000 tons displacement for battleships, 6000 tons for cruisers and 800 tons for destroyers. Considering how far these maxima were below the standards of other navies, it was thought that the German Fleet would be permanently crippled, for even if they built up to the number of units allowed by the Treaty, it seemed as though they were bound to be so much less powerful than those of other nations that there would be no need to worry about what they could do. German scientists, metallurgists and naval architects immediately set themselves to get more out of every 1000 tons of displacement than had ever been attempted before and on paper their results were certainly remarkable. The 6000-ton cruisers and 800-ton destroyers all possess remarkable features for ships of such modest size, but it was the 10,000-ton "pocket battleships" of the *Deutschland* type which astonished the world. Welding was extensively used in their construction and the accounts which were published with official blessing of the lightness of their Diesel machinery were incredible to most professional men. Then rumors began that all these expedients for saving weight were not as satisfactory as they might have been, and that the welded hulls in particular were giving much trouble. Consequently, cracks developing in the plates a few inches from, and parallel to, the welded joint. Active service conditions on the coast of Spain appear to have confirmed these rumors and to have shown that they were not exaggerated.

CORROSION TESTS OF WELDED LOW-CARBON STAINLESS STEEL. Journal of the Franklin Institute, Philadelphia, Pa., February, 1937.

Laboratory tests are frequently used to determine the resistance of a material to corrosion under certain conditions. The value of these tests as an indication of the future behavior of materials in service depends largely upon the type of service and upon the interpretation of the results.

Several methods have been proposed for testing stainless steels, some of which are embodied in specifications for these materials. Three methods have been investigated recently by George A. Ellinger and Leon C. Bibber of the Bureau's metallurgical division, in connection with the welding of stainless steel containing about 0.06 per cent of carbon.

A solution of copper sulphate in sulphuric acid did not noticeably attack either plate or weld metal that had been heated to any temperature, although this reagent has been reported to cause intergranular corrosion in stainless steels of higher carbon content.

Concentrated nitric acid was found to attack carbides which had been localized at grain boundaries. The acid attack destroyed the cohesion between the grains by dissolving or decomposing the carbides, thus allowing the grains to become loosened and ultimately to fall away from the material. This type of attack was found only in plate metal which had been heated to 650 degrees C. and which contained carbides localized at the grain boundaries. Carbides in weld metal were usually found in areas of delta ferrite and not in the grain boundaries, regardless of heat treatment; consequently the attack by nitric acid on weld metal was slight.

A solution of hydrochloric acid and water (equal parts) attacked the plate metal severely. Heat treatment of the plate did not appreciably change this rate of attack. Weld metal that was not heat treated was attacked at approximately the same rate as plate metal. After annealing at either 650 degrees C. or 980 degrees C., weld metal was more resistant to attack than plate metal.

ASSOCIATION NOTES.

ANNUAL BANQUET.

The Annual Banquet of the Society was held at the Willard Hotel in Washington, D. C., on Thursday, April 15, 1937. Of the many banquets which have been given, that of this year was truly outstanding, both in enjoyment and in the attendance of a most comprehensive gathering of the Engineering profession of our Country. Detailed information relative to this event will be found elsewhere in this number.

ERRATA.

Commander L. P. Smith, U.S.N., requests that those interested make the following correction in "Table III, δ Correction" of the article "Quick Approximation for Preliminary Propeller Design" on p. 561 JOURNAL of A.S.N.E., Vol. XLVII, No. 4, November, 1935:

In the column headed B.T.F.

(a) Change .04 to .06.

(b) Change .06 to .04.

The following members have joined the Society since the publication of the February, 1937, JOURNAL:

NAVAL.

Girard, E. J., Lieutenant, U.S.N.R., 1420 New York Avenue, N. W., Washington, D. C.

Olson, L. B., Lieut. Commander, U.S.C.G.

Swerdlin, Manney, Lieutenant, U.S.N.R., S.S. *President Hoover*.

Ward, Benjamin P., Lieut. Commander, U.S.C.G.

Wilcox, Ben C., Lieut. Commander, U.S.C.G.

CIVIL.

Bester, Leonard R., 90 St. Marks Place, Staten Island, N. Y.

Hodge, Dr. James C., Babcock & Wilcox Company, Barberton, Ohio.

Knowlton, Frank A., Central Drafting Office, Navy Yard, New York, N. Y.

Steele, Maurice G., 4109 Roland Road, Baltimore, Md.

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ASSOCIATE.

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Cannon, R. A., Birdsboro Steel Foundry and Machine Co., Birdsboro, Pa.

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Leach, Robert H., care Handy & Harman, Bridgeport, Conn.

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Wylie, J. C., 218 Forest Ave., Glen Ridge, N. J.